ARISSat-1

The AMSAT® Journal

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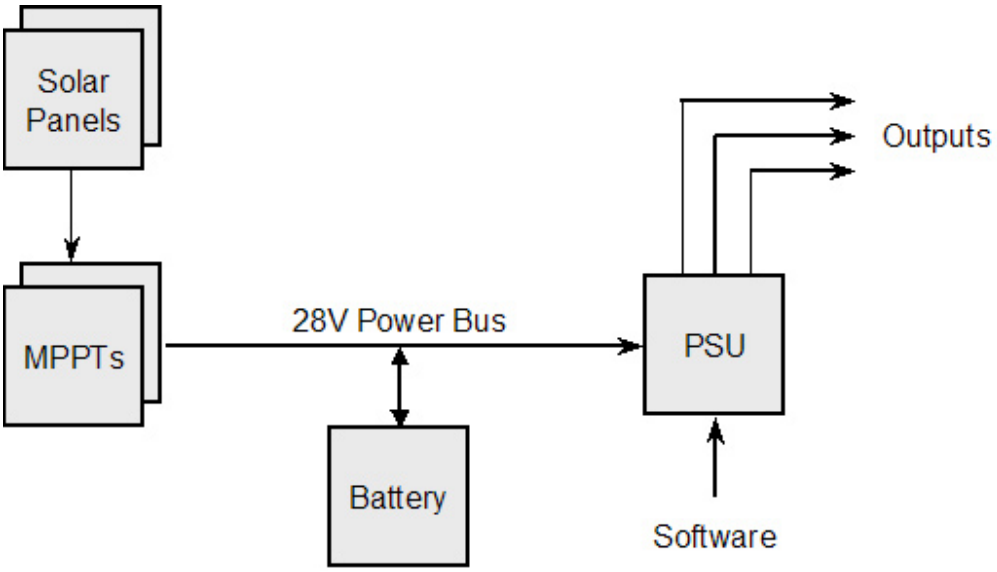
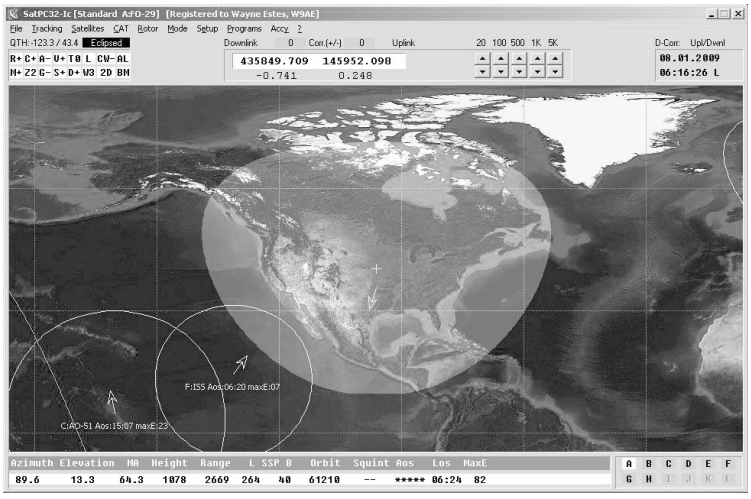


The ARISSat-1 Power System



Beginners - How to Begin? (Part IV)

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Call the AMSAT-NA office at 301-589-6062 for questions on any or all of these ways you can help build new and exciting satellites.

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AMSAT Announcements

AMSAT Straight Key Night - 2011

Many thanks to all who participated in AMSAT's Straight Key Night on OSCAR 2011. This year's event was held in memory of Dick Peacock, W2GFF. Despite the frequent necessary power-management shut-downs of AO-51, activity was generally good, with AO-7, FO-29 and VO-52 picking up the load. A big "Well Done!" to all of the command stations.

The following participants each received one or more "Best Fist" nominations:

AA5PK, JH7UJI, JM1SBU, JR0EFE, K9CIS, N1AIA, N4ZQ, N5AFV, N9AMW, ON5NY, PR7VX, PU4RON, VA7MG, W9EN, WA5KBH, WB2SIH, WC7V, WD9EWK, 9A2EY

As can be seen from the list, from its very modest, informal beginnings on the North American east coast AMSAT net in the 1970s, SKN on OSCAR is now a worldwide event. Long may it continue and we hope to see you next year!

73,

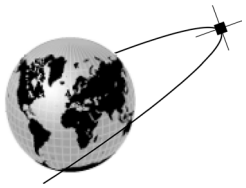
Ray, W2RS

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.



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WE DID IT! After nearly five years there is another Amateur Radio experiment that will be deployed from the International Space Station. As I'm writing this column, ARISSAT-1/RadioSkaf-V/KEDR has been delivered to the ISS and we're awaiting release during a spacewalk officially known as "Russian Segment EVA28" scheduled for 16 Feb 11.

The road to success has been a long and sometimes frustrating one. Following the SuitSat-1/AO-54 mission in 2006, work started on designing a successor, one that would incorporate several enhancements that would extend the life of the mission and provide more robust satellite services. SuitSat-2 was going to benefit from the lessons learned from SuitSat-1 as well as expand the technical envelope. A group of enthusiastic volunteers was assembled to design and build the modules that would be enclosed in a surplus Russian Orlan space suit.

Unfortunately, a number of events stymied the effort, including technical challenges that significantly slowed progress. Development work took much longer than originally envisioned, partly due to revisions to the project plan. The tendency was to 'cut metal' before doing the project management work needed to ensure that a well thought-out design on paper was created to catch problems before starting actual construction. Unanticipated technical issues caused many redesigns. It also became apparent that additional technical support was needed with several subsystems. Fortunately, the talent was available to step in and assist. Under the leadership of Project Manager Gould Smith, WA4SXM, who joined the project in 2008 and AMSAT VP-Engineering Tony Monteiro, AA2TX, who joined the project in late 2008, development work started to gel. Tony, for example, developed the software for the software defined transponder (SDX), the box that allows four individual transmissions to occur at the same time on the two meter downlink (CW beacon, BPSK telemetry, FM voice messages and the 16 kHz wide transponder downlink).

Then, in July 2009, we were informed that an Orlan Suit would not be available. In stepped Bob Davis, KF4KSS, and a team of mechanical engineers to design a space frame that would accommodate the modules and the solar panels needed to keep the project going. With thermal analysis conducted by Dick Jansson, KD1K, we now understood how cold the satellite would operate in space and so provisions were made to add passive thermal enhancements to protect the satellite. These individuals, coupled with the volunteers at Microchip (including Steve Bible, N7HPR; Jerry Zdenek, N9YTK; Joe Julicher, N9WXU and Tim Moffat) who were the folks designing the IHU, MPPTs and PSU, put in untold hours getting things designed and built. We were also fortunate to have volunteers such as Chuck Green, NOADI, (who built the spaceflight modules), Larry Brown, W7LB, (who built the harnesses), and Bill Ress, N6GHZ, (who designed and built the RF modules). There were over 40 other volunteers who have supported this project as well.

What many may not realize is that SuitSat-2 and later ARISSat-1 was in fact a Russian supported project conducted under the umbrella of ARISS (Amateur Radio on the International Space Station). As a delegate of ARISS-International, AMSAT agreed to build the equipment and deliver to RSC-Energia for upload to the ISS and subsequent deployment during EVA. RSC-Energia's agreement to provide upload mass on a Progress unmanned ISS resupply vehicle and allocate training time for cosmonauts and then perform the deployment was based upon the educational aspects of the project. ARISSat-1 is designed to support up to four experiments. The Kursk State Technical University developed and provided a student experiment to measure the vacuum of space. It is this educational connection that justifies national space agency resources be allocated for an Amateur Radio-based satellite.

Recognizing the significant educational potential, the NASA Office of Education has strongly supported the development efforts for ARISSat-1. ARISS is supported by the Teaching from Space Office, a part of the NASA Office of Education that focuses on K-12 student projects. It is the educational benefits of ARISS school contacts that have allowed Amateur Radio to have a presence on the ISS. Seeing ARISSat-1 as a test bed for future US-based university level student experiments that could be deployed from the ISS, the support from

continued on page 21 ...

Getting Started on the Amateur Radio Satellites (Part IV)

by Keith Baker, KB1SF/VA3KSF, kb1sf@amsat.org

(The bulk of this article was previously published as "Working Your First Amateur Radio Satellite (Part IV)" in the August 2010 issue of *Monitoring Times*, Brasstown, NC 28902)

I trust you are enjoying this multi-part series of articles designed to take the mystery out of operating though Amateur Radio's current fleet of orbiting communications satellites. In this installment I'll quickly review some of the more sophisticated satellite tracking software that's currently available. I'll also share some tips on choosing a radio and accessories specifically designed for satellite work and then wrap up this latest getting started chapter with a final word about feed lines and connectors.

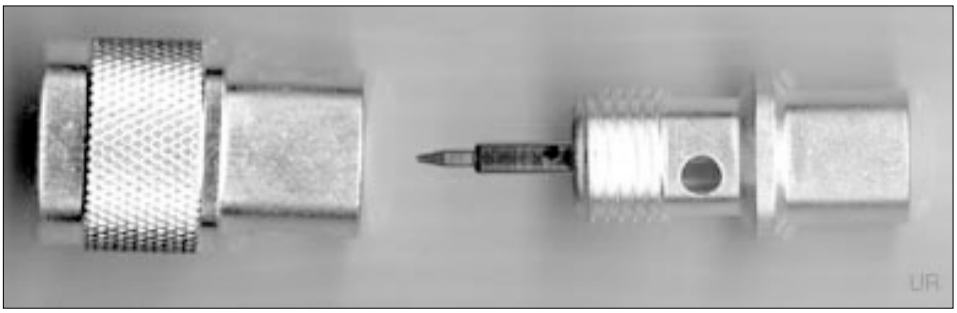

Figure 1: This two-piece, Type-N connector makes the age-old chore of working with N connectors a breeze. (Courtesy: Universal Radio) [Ed. - See the sidebar on the next page.]

Tracking Topix

As I said in the kickoff article to this series, to listen for (or communicate through) an Amateur Radio satellite, you first have to know when it will be in range of your station. Fortunately, most of us now have computers in our operating positions to assist us with this (once rather arduous) task. Currently, organizations such as our own Radio Amateur Satellite Corporation (AMSAT) now offer Internet-based satellite tracking information in graphic form via our Web site **(www.amsat.org/amsat-new/tools/predict/satloc.php).** You can even get quick pass predictions from AMSAT for a handful of the more popular satellites simply by entering your Maidenhead grid square (or your latitude and longitude) into the online prediction engine at **www.amsat.org/amsat-new/tools/predict/index.php.** However, if you are serious about satellite work, you'll eventually want to use something more permanent to run on your own home computer.

Over the years, PC-based tracking programs have become more sophisticated as the computing power available to run them has improved. Today, a number of them can track multiple satellites using highly sophisticated graphical interfaces. Some even send altitude and azimuth aiming data to your antenna rotators for the ultimate in hands off tracking. A number of these programs can also automatically tune your radio to the proper uplink and downlink frequencies to compensate for Doppler shift as the satellite of interest whizzes overhead.

The AMSAT Web site hosts an extensive archive of various satellite-related software programs (including tracking programs) for various computer platforms at: **www.amsat.org/amsat-new/tools/softwareArchive.php#pc.**

For Windows 95/98/ME/NT/2000/XP/Vista/Windows 7 users, AMSAT also offers a superb tracking program called SATPC32 (See Figure 2). Written by Eric Eichmann, DK1TB, this program features automatic Keplerian Element download and voice announcements when satellites are in range, multiple world map projections with zoom capability, as well as support for a number of antenna rotator tracking interfaces.

For a small monetary donation to AMSAT, SATPC32 is currently available in either direct download or CD ROM format via the AMSAT Web site at: **www.amsat-na.com/store/item.php?id=100017.** You can also download a trial version of the latest release of SatPC32 from the author's Web site at: **www.dk1tb.de/downloadeng.htm**. However, this version requires you to re-enter your latitude and longitude every time you start the program. To fully activate your copy of SATPC32, you must obtain a registration code via the AMSAT online store or by calling Martha at the AMSAT office at 1-888-322-6728.

Tracking software for Macintosh users is also available from AMSAT for a small monetary donation. The current offering is MacDoppler, which provides a number of levels of station automation, from assisted Doppler tuning and antenna pointing right on up to fully automated satellite gateway operation. More information on MacDoppler can be found at: **www.amsat-na.com/store/item.php?id=100164,** or, again, by calling the AMSAT office.

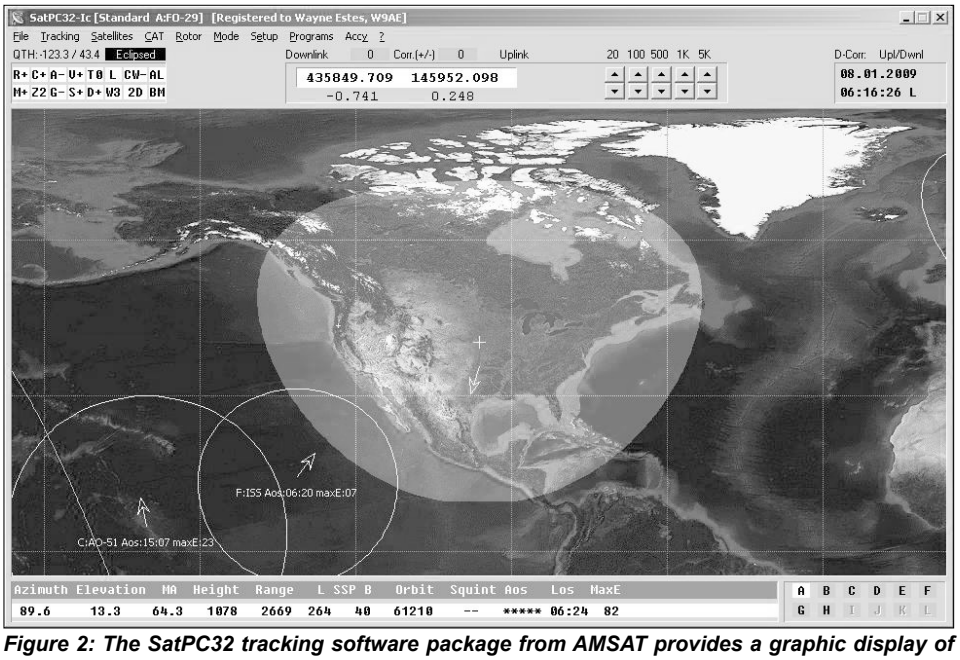

Figure 2: The SatPC32 tracking software package from AMSAT provides a graphic display of multiple satellites as well as a source to tune your radio for Doppler shift. It can also drive a rotator interface to automatically turn your satellite antennas. (Courtesy: AMSAT)

Figure 3: The Alinco DJ-G7T/E is a 5w, dual band, hand-held FM transceiver that very nicely works the FM "birds". (Courtesy: Alinco Incorporated)

Feeding your Tracking Program

Whichever tracking program you ultimately choose, it is important to always keep your Keplerian element file up-to-date. That's because gravitational interactions of the Sun, the Moon and the Earth on orbiting satellites (as well as the residual air they encounter where they operate) all conspire to slow them down just a tiny bit on every orbit. Over time, these orbital changes will directly affect when a particular satellite will be in range of your station.

In addition, the crew of the International Space Station (ISS) periodically fires the station's onboard thrusters to change its orbit. Usually, this is done to move the ISS out of the way of space junk or to boost its orbit to keep it in space. If you are tracking the ISS, this action, too, will directly affect when the ISS will be in range of your station.

Because satellite orbits change over time, most veteran satellite operators update their Keplerian element files in their tracking programs once every few weeks or so. The AMSAT Web site (**www.amsat.org/amsat-new/tools/keps.php)** offers Keplerian element files for free download in a number of formats, including the more verbose AMSAT format (for manual tracking) to what are called NASA Two Line Elements suitable for file capture and later upload into your tracking software.

Satellite Radios

As I've said in previous columns, while hand-held radios and antennas are great for hit or miss satellite contacts, if you are serious about satellite work, eventually you'll want something more permanent for your home station.

Over the years, several Amateur Radio manufacturers have offered base station radios specifically equipped to work the satellites. This equipment usually offers all-mode VHF/UHF capability and can also transmit and receive in full duplex mode, meaning the radio has the ability to transmit signals on one band and simultaneously receive them on another. While not absolutely necessary, this feature makes it much easier to know if your signal is actually getting into (and through) the bird. It also helps you tune your radio to compensate for Doppler shift as the satellite whizzes overhead.

A good place to start your search for a satellite capable, full duplex radio is with a list painstakingly complied by Andrew Koenig, KE5GDB, at**: http://thathamkid.com/fd_radios.html**. While there are only a handful of new, full duplex radios on the market today, many older (but still perfectly functional) satellite-capable radios can still be found on the used market. Some time spent scouring the various Amateur Radio bulletin boards that offer used equipment (such as **www.qrz.com** or **www.eham.net**) may pay off in a somewhat older, but still perfectly functioning satellite radio at a fraction of the cost of a new one.

And while a single, all in one, full duplex base station radio is nice to have, for many years I operated on the satellites using two separate radios. One was an all-mode VHF radio (a Kenwood TS-711A) and the other was an all-mode UHF radio (its 70 cm companion, the Kenwood TS-8llA). And while I had to manually tune each of them to keep up with "Dr. Doppler", this setup still provided me with many hours of solid satellite radio time.

Likewise, if a full duplex, all-in-one box is beyond your means, you can still adapt a number of the all-mode VHF/UHF-capable base or mobile radios now on the new (or used) market for satellite work. For example, many satellite operators have very successfully adapted a pair of all-mode Yaesu FT-817 (so-called QRP) radios (or its more powerful cousin the FT-857) for both channelized FM and linear transponder satellite work … one radio for the VHF/UHF uplink and one for the VHF/UHF downlink

Finally, a Type-N Connector for the Masses!

PL-259 connectors are usually easy to assemble and solder. However, if you are like me, working with N connectors has always been problematic. The typical Type-N connector consists of up to 6 components, all of which must be carefully soldered and then seated to seal out moisture properly. However, no matter how carefully I assembled and installed feed lines using the old Type-N connectors, I often found that (particularly in outdoor applications) the slightest pull on the coax usually resulted in a detached (or shorted!) N connector.

Thankfully, innovation has now come to the rescue! (See Figure 1.) This two-piece N connector is a silver plated, gold tip connector of top quality that solders and assembles much like a PL-259. Yet, this version maintains most of the bumpless impedance qualities of the classic Type-N. Even the same UG175 and UG176 reducers for PL-259s can be used for smaller cable types.

Those of us who are all thumbs when it comes to working with coax connectors need never again struggle with a Type-N! A good source for this modern, PL-259-like version of the classic Type-N is Universal Radio in Reynoldsburg, Ohio. (**www.universal-radio.com/catalog/parts/nconn.html**) as well as R & L Electronics in Hamilton, Ohio (**www.rlham.com/cgi-bin/shop/modellookup.dbw?MODEL=N9913**).

Figure 4: The Yaesu FT-847 is a 1990's-era, all-mode, HF/VHF/UHF base station radio that was specifically optimized for full duplex satellite work. While now out of production, it can sometimes still be found on the used market. (Courtesy: www.rigpix.com)

Figure 5: The ICOM IC-910H is a late model, all mode VHF/UHF base station that was specifically optimized for full duplex satellite work. This radio has recently been dropped from the ICOM lineup in favor of a newer satellite-capable model. However, start looking for the '910H to show up on the used market. (Courtesy: www.rigpix.com)

(see photo on page 7).

As I said, unfortunately, fewer and fewer newly manufactured radios these days have the capability to operate in full duplex mode. But, fortunately, there *are* still a few of them on the market … with more to follow.

The Alinco DJ-G7T/E

Priced at about $300 retail, the new Alinco DJ-G7T/E (see Figure 3 on previous page) is one such radio suitable for hand-held satellite operation on our FM birds. Besides being able to operate in full duplex mode on the 144 MHz, 430 MHz and 1200 MHz bands, it sports a 5w transmitter, 50 pair of programmable scan memories and a host of other bells and whistles of interest to the amateur satellite user.

Kenwood's venerable TS-2000

As of this writing (early January 2011) the only base station amateur transceiver on the new equipment market that also enables full duplex satellite work is the Kenwood TS-2000 (see Figure 6). Lately, thanks to Kenwood incentives, the radio can be purchased for substantially less than its current suggested retail price of around $1700. It offers the beginning satellite user a superb value in a do everything rig. This HF/VHF/UHF all mode radio sports a 100w transmitter for HF through 2m (50w on 70cm), dual channel receive, digital signal processing (DSP), a 16 bit processor, built in TCXO for superb frequency stability, as well as a built in auto antenna tuner for 160 through 6 meters.

For satellite work, the TS-2000 uses 10 dedicated memory channels with the ability to synchronize the transceiver between either normal or reverse tracking of uplinks (transmitting) and downlink (receiving) frequencies.

ICOM's new IC-9100

ICOM has been another strong supporter of the amateur satellite community over the years. Lately, they, too, have been filling a high end niche with some outstanding satellite equipment. The bad news is that they recently discontinued sale of their very popular IC-910H VHF/UHF all mode base radio (see Figure 5). The good news is that they are now in the process of replacing the '910 with what promises to be an even more robust, all in one box satellite radio with their new IC-9100 (see Figure 7).

Figure 6: The Kenwood TS-2000 is another all mode HF/VHF/UHF base station radio suitable for full duplex satellite work that is, as of this writing, still in production. (Courtesy: Kenwood USA)

The '9100 is slated to provide 100w on all bands and all modes HF through 2m, and 75w on UHF. It will simultaneously receive on two different bands and will work as if there are two different receivers in one radio. The radio also sports 32 bit DSP and offers ICOM's increasingly popular D-Star, digital communications capability to boot.

In the satellite mode, the '9100 will synchronize uplink and downlink frequencies via 20 satellite memory channels that allow for storing operating modes and tone settings as well as other satellite-unique parameters. Again, as of this writing (early January 2011) sale of the IC-9100 in the United States was still awaiting FCC approval. Manufacturer's suggested retail price when it finally hits the shelves of dealers is expected to be in the $4000 range.

Now, none of this discussion is intended to provide a personal (or official) endorsement of any particular manufacturer's radio. Just like those seemingly endless arguments about Ford versus Chevy automobiles, each of us has our own personal preferences about a particular manufacturer's radio equipment. The bottom line here is that you must still do your homework to learn which features each satellite-capable radio offers and how they all compare with what you can reasonably afford. That activity has *always* been an essential part of our Amateur Radio hobby, and shopping for radio equipment to work the birds is no exception.

Preamps

As the downlink signal from these satellites is already weak when it strikes your antenna, another nice to have (but not absolutely necessary) addition to your base station setup is a receive preamplifier to boost the satellite's downlink signal. These preamplifiers (or preamps as we call them) come in many shapes and forms. Some are integrated into the radio itself (or into external, so-called brick amplifiers) while others are designed to be mast-mounted nearer to your antenna (see Figure 8).

Over the years, I've found the mast-mounted

Figure 7: Slated to hit the market "soon" is, ICOM's IC-9100. Its 32-bit processor will work all satellite modes, HF through UHF with many additional "satellite friendly" features. (Courtesy: ICOM America)

variety are best because they boost the satellite's weak downlink signal where it is strongest, that is, *before* any of that weak satellite downlink signal is lost in the feed line to your station. However, unless the preamp is specifically equipped with internal switching relays, it is VERY important to remember that transmitting a signal back through one of them will often prove fatal to the device. I've smoked more than one of these in my time this way!

A Word About Connectors

While I have already discussed the importance of using a high quality, low loss feedline between your satellite antenna and your radio (and keeping that feed line length as short as practicable), it is also important to use the very best connectors you can afford. Just as with choosing your feed line, if you try to skimp on the connectors for the feed line connecting your antenna to your radio, you could loose a significant portion of your signal through those connectors as well.

Remember, every dB of attenuation that weak satellite signals encounter while traveling from your antenna to your radio is a bit of the downlink you won't hear. A 3-6 dB loss from using cheap, HF-only rated coax and poor quality connectors can turn a marginal VHF or UHF downlink signal into one that simply isn't there.

Connectors add to line losses by creating impedance humps that act like little resistors in the line. At HF (and to some extent at 6m and 2m) you can usually get by with using the common SO-239/PL-259 connector combination. However, at higher frequencies (such as at 70 cm and above where many of our Amateur Radio satellites operate) most satellite-capable equipment comes equipped with a Type-N connector (see sidebar). The type-N connector, when properly installed, will help minimize these small mismatches in the feed line which, in turn, will allow a greater portion of that (already weak) satellite downlink signal to make its way to your operating position from your satellite antenna.

As I also noted in a previous column, it is critically important make sure that these connectors are well seated and well sealed when installed at your antenna. Otherwise, your coax will very quickly become waterlogged and then you'll *really* have line losses to contend with! One popular method is to wrap electrical tape tightly around the connectors, or use one of the many available hand-moldable compounds sold just for this purpose.

Wrap Up

I hope you are still enjoying this short series of satellite primers all designed to help get you started using our Amateur Radio satellites. But, now is *not* the time to stop your learning! The AMSAT Web site **(www.amsat.org)** offers a wealth of practical, hands on information (both free or for a small monetary donation) to help fuel your growing interest in the birds. What's more, because of the publications and discounts on software and other items you receive when you join, a sustaining membership in (and additional supporting donations to) your national, non-profit AMSAT organization is always a good way to keep expanding your knowledge while also helping insure new Amateur Radio satellites will continue to be built and launched.

In future columns I'll be exploring some other aspects of amateur satellite operation as well as some more information on how our Amateur Radio satellites get their names.

See you then.

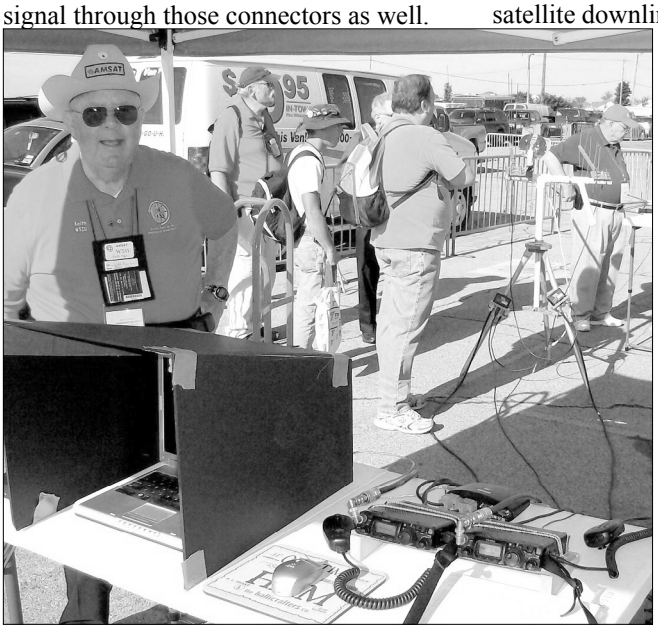

Photo 1: AMSAT's Keith Pugh, W5IU, uses a pair of Yaesu FT-817 QRP rigs (one for the uplink and one for the downlink) for his Dayton Hamvention satellite demonstration station. (Courtesy: KB1SF)

Figure 8: Mast-mounted preamps, such as this one from SSB electronics, boost weak satellite downlink signals at the antenna feed point where those signals are strongest. (Courtesy: SSB Electronics)

The ARISSat-1 Power System

by Tony Monteiro, AA2TX, aa2tx@amsat.org

Introduction

Power is a precious commodity on a satellite. It can be challenging and often costly to generate even modest amounts of it in space. All of the power to run ARISSat-1 comes from our sun. The power system includes solar panels, maximum power point trackers (MPPTs), a rechargeable battery, a power supply unit (PSU) and power management software as shown in Figure 1.

Each solar panel is connected to an MPPT, which is a special type of DC-to-DC power converter. In sunlight, the solar panels and MPPTs provide power to charge the battery and supply the PSU. In eclipse, the battery provides all of the power to run the satellite. The power management software running on the Internal Housekeeping Unit (IHU) monitors and apportions the available power amongst the satellite subsystems. This software operates autonomously and is designed to maximize the functionality of the satellite while balancing the need to preserve the battery life and prevent inadvertent power down in eclipse.

Solar Panels

ARISSat-1 has a solar panel on each of its 4 sides plus the top and bottom for a total of 6 panels. These solar panels were donated to the project by NASA and were left over from the Small Explorer (SMEX) satellite program [1]. The panels are series connections of 50 individual cells and each panel can produce around 19 watts [2]. The electrical curves for the panels in full sun at 28 C are shown on the chart of Figure 2.

The electrical characteristics of the panels vary with illumination and temperature. The maximum current varies directly with illumination and that depends upon the angle between the sunlight and the panel. The open circuit voltage and power available vary inversely with temperature. On ARISSat-1, the solar panels will generally be below 28 degrees C so they can deliver slightly more power than what is shown on the chart.

Since the SMEX panels are made of series connected cells, they are very sensitive to shadowing. A shadow cast on even a single cell can reduce the panel output to zero. The handles and antennas on ARISSat-1 protrude from the satellite space frame and at certain sun angles will cast such shadows on the solar panels. This directly affects the total power available from the panels.

Maximum Power Point Trackers

Each solar panel is connected to a maximum power point tracker (MPPT) circuit. The MPPTs are special DC-to-DC power converters that are designed to extract the maximum power available from each solar panel. Please see Figure 3. The solar panel outputs are fed to a switching supply that converts the DC input to a high frequency signal, drives an inductor and then rectifies the output back to DC. Like a typical switching supply the current drawn from the input is a function of the pulse width of the switching transistors. On a normal power supply the pulse width is controlled to maintain a constant output voltage. The MPPTs however, adjust the pulse width to maximize the input power. The solar panel current and voltage drive what is known as the Hill-Climbing algorithm, which is implemented in software on a microcontroller. The name refers to the way that the algorithm "climbs" the power hill on the solar panel electrical curve as shown by the dotted line in Figure 2. It works as follows; the pulse width on the switching transistors is adjusted a tiny bit (i.e., wider or narrower). If the input power went up, then it adjusts the pulse width again in that direction. If the power went down, then it adjusts the pulse width in the opposite direction. This combination of making a tiny change and then seeing what happens is repeated continuously. In this way, the maximum input power at the top of the hill is eventually reached. As the panel illumination changes, the algorithm will automatically find the new maximum power point.

Each MPPT also has an over-voltage detector on the output side and will cut back if the output goes above 36 volts. This is to prevent over-charging the battery. The MPPT outputs are all connected in parallel to drive the 28V power bus.

The power output from an MPPT depends on both the electrical efficiency of the power conversion and the dynamic response to a change in the illumination of the panel. The measured dynamic response is shown in Figure 4. This is the MPPT output versus time in response to a step change on the input from a dark to a fully illuminated panel. As tested, the power maximum is found in 140 milliseconds at an 85% power conversion efficiency.

Satellite Spin

As the satellite spins, the solar panels go in and out of sunlight. The shading from the handles causes the side panel illumination to change very abruptly during a satellite revolution. Similarly, the shading from the antennas can cause the power from the top and bottom panels to change very abruptly. These effects challenge the dynamic tracking ability of the MPPTs.

Bob Davis developed a model to combine the effects of the sun angle, shadowing from the handles and antennas and the satellite rotation about its axis to predict the illumination of each of the solar panels. The author incorporated Bob's illumination model with electrical models of the solar

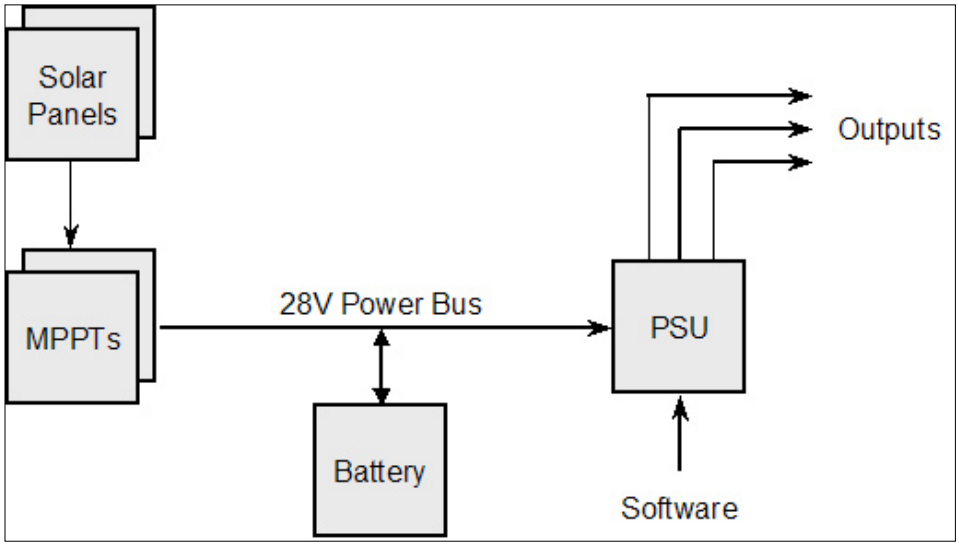

Figure 1: Power System Diagram.

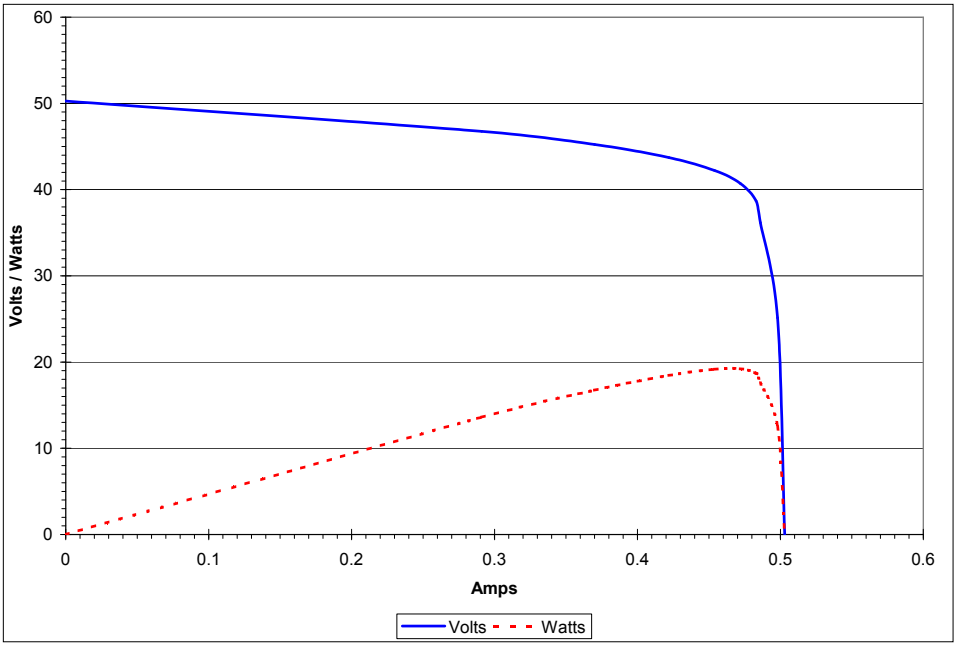

Figure 2: Solar Panel Characteristics.

panels and MPPTs to create a power system simulator program. The simulator predicts the combined output power from all of the MPPTs at various sun angles and at various satellite spin periods. The minimum spin period is expected to be at least 4 seconds per revolution and the simulator output under this condition is shown in Figure 5. The solid line is the average power and the dashed line is the minimum over one satellite revolution. The beta angle is the angle the satellite makes with the sun. An angle of 0 degrees means the sun is illuminating the side of the satellite. An angle of 90 degrees means the sun is illuminating the top (+90 degrees) or the bottom (-90 degrees) of the satellite. ARISSat-1 is symmetrical about the beta angle so only 0 to 90 degrees is shown on the chart.

As can be seen, the average power from the MPPTs can vary from a high of over 18 watts to a low of about 11 watts depending on the beta angle. However, the minimum power output as the satellite spins can be much lower and can go down to only 2.5 watts at an angle of 76 degrees. This is the result of the shadow cast from the antennas on the top and bottom solar panels. If the satellite electronics requires more power than the MPPTs can provide, the power will be supplied by the battery. If the battery is unable to provide this power, the satellite will power down. Of course in eclipse, all of the satellite power is provided by the battery and so its health is critical to proper operation.

Battery

ARISSat-1 has an 825M3 Russian space suit battery for storing power. [3] This battery was donated to the project by the Russian space agency; RSC-Energia. Internally, the battery has 18 rechargeable silver-zinc cells and its specifications are shown in Figure 6. [4] A silver zinc cell consists of silver and zinc electrodes, a potassium hydroxide electrolyte solution and a very thin separator between the electrodes that is typically 6 mil cellophane (1 mil = .001 inch).

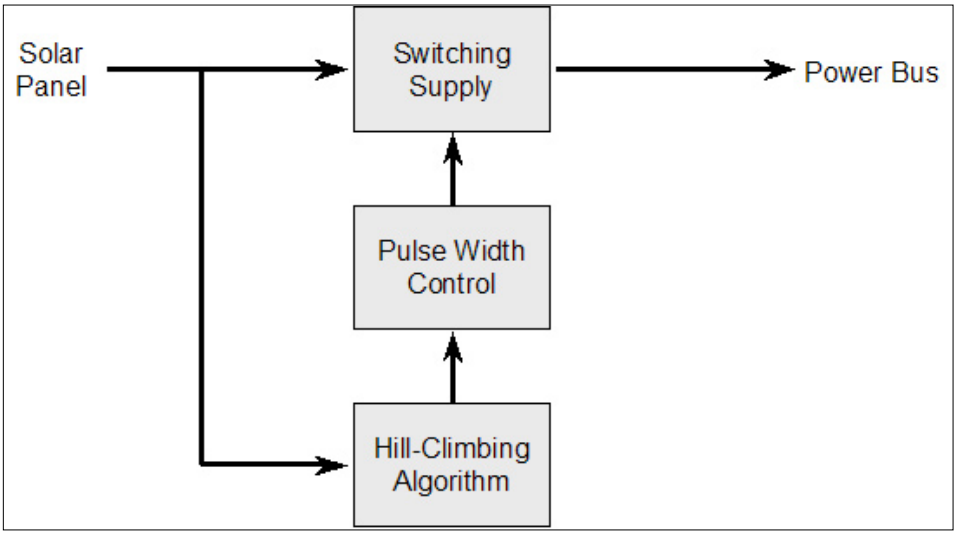

Figure 3: MPPT Operation.

Silver-zinc batteries are widely used on spacecraft because they provide high power, are lightweight and are inherently safe. You can short-circuit the output of a silver-zinc battery indefinitely and it will not catch fire. This is an especially useful characteristic on manned missions like those on the International Space Station (ISS.) Since ARISSat-1 will be deployed from the ISS, it is subject to much more stringent safety requirements than a typical satellite and the donated silver-zinc battery is a big help in meeting the rigorous safety requirements. The disadvantages of silver-zinc batteries are their very high cost, poor capacity at low temperatures, limited wet life and limited charge/discharge cycles.

The 825M3 operating temperature is specified as +6 to +45 degrees C but a thermal analysis provided by Dick Jansson shows that the battery will likely reach –30 degrees C after deployment. This is much lower than the specified range and there is no data available from the manufacturer to qualify operation at these temperatures. But, based on discussions with Yardney Technical Products, a company that manufactures similar types of batteries, the cold discharge performance was estimated [5] and is shown in the chart of Figure 7. The chart shows that the battery capacity would be reduced to about 6 amp-hours versus 14 amp-hours in the nominal case.

To warm up the battery to improve its capacity, a thermal blanket will be used. Silver-zinc batteries do not generally generate a lot of heat, but the blanket will help capture what little is produced. About 12 to 18 milliwatts of heat are expected to be produced during discharge and 20 to 140 milliwatts during charging.

There is no charge performance data available for the 825M3 battery either but again, based on information supplied by Yardney, a charge curve was estimated and is shown in Figure 8. This chart shows the battery terminal voltage as a function of its charge capacity. There is a noticeable voltage

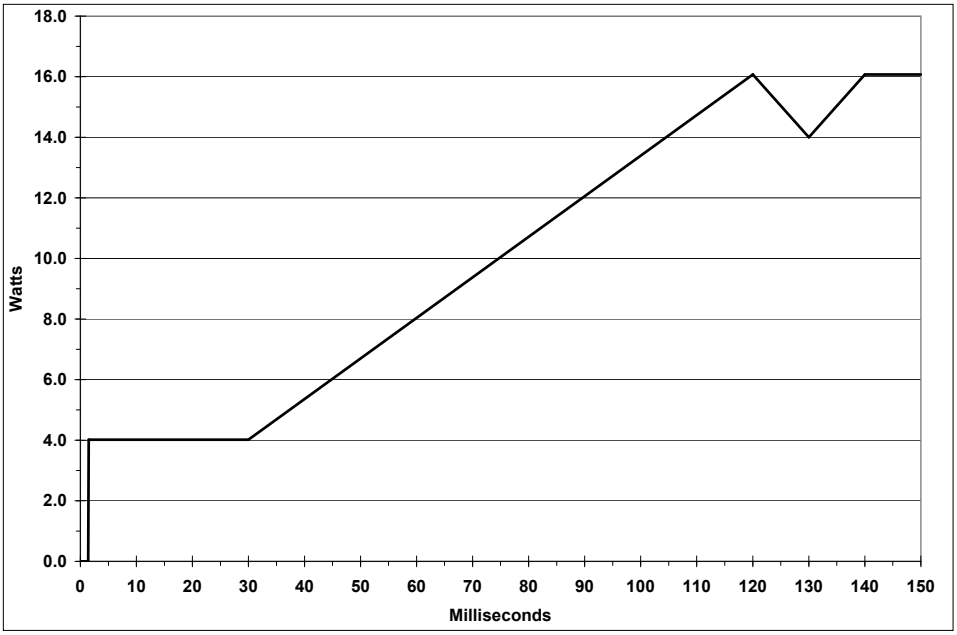

Figure 4: MPPT Dynamic Response.

spike at approximately 30% of charge. This is typical of all silver-zinc batteries and is due to a chemical change in the electrode from silver-oxide to silver peroxide at this point in the charge cycle chemistry. As the charge is increased, the battery terminal voltage will settle into the range of 34 to 35 volts until the battery is fully charged. When fully charged, the terminal voltage will be approximately 36 volts and is limited by the MPPT over-voltage protection circuits.

The charge efficiency of a battery is the discharge capacity divided by the total charge needed to fully replenish it. The charge efficiency of the 825M3 is unknown and not specified. A recent technical paper implies a typical silver-zinc battery charge efficiency of around 80% [6] but other papers show a wider range from 63% to 98% and a high dependence on the number of charge-discharge cycles. The custom designed silver-zinc battery used in the Mars Environmental Survey Mission showed an average charge efficiency of 89% while being subjected to a simulated mission with 30 cycles [7]. Without any actual data, the charge efficiency of the 825M3 was assumed to be at least 80%.

The maximum life of a silver-zinc battery is limited by the effect of separator deterioration from exposure to the highly alkaline electrolyte solution. This is called the wet-life of the battery and the 825M3 is rated for a minimum of 1 year. Since ARISSat-1 will re-enter the atmosphere in less time, the wet life is not expected to be a concern.

However, battery charge cycling is a very significant concern. As a silver-zinc battery is discharged and then recharged, dendrites grow from the silver electrode that puncture the thin separator and come in contact the zinc electrode. As these dendrites grow, they cause mini short circuits that result in a reduction of the capacity and an increase in the load across the battery terminals. At some point, the battery will become a dead short. This is a major concern because the 825M3 battery is specified for a total of only 5 cycles but in orbit, will see 16 cycles every day. Fortunately, it is possible to extend the number of cycles by limiting the current discharge to a small percentage of the maximum capacity. There is no data available on operating the 825M3 this way but, as before, estimates were made based on information provided by Yardney. Projections indicate that by sufficiently limiting the discharge current, it should be possible to maintain battery operation for 1000 cycles or more.

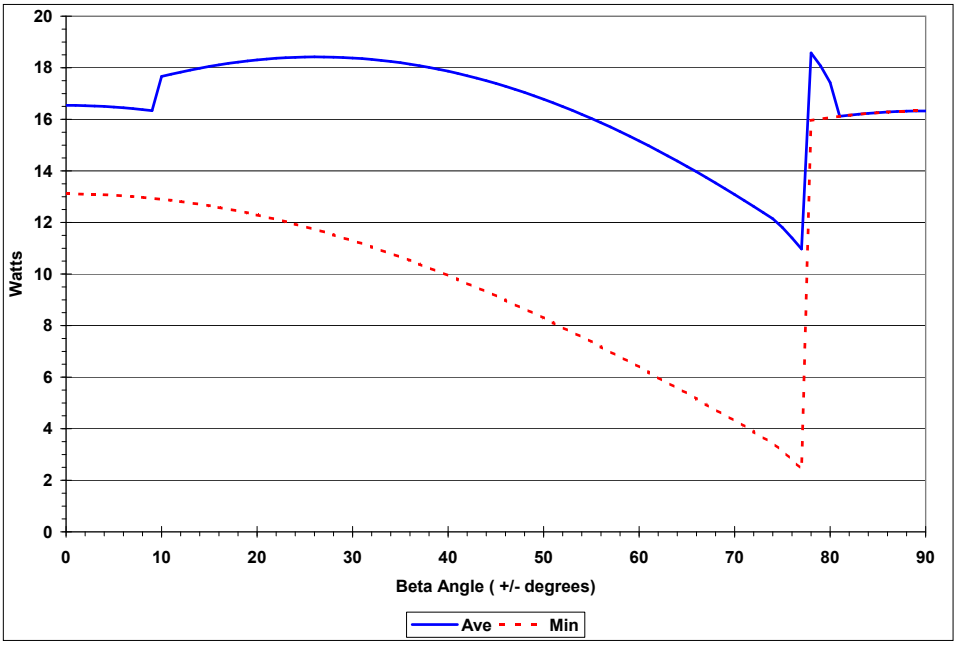

Figure 5: Power System Output.

Power Supply Unit

The Power Supply Unit (PSU) includes a number of DC-to-DC power converters that take power from the 28V power bus and provide the +12V, +8V, and +5V needed to run the satellite electronics. The voltages can be switched on or off to the various satellite circuits. The PSU provides a serial communications link to the IHU which allows software on the IHU to control these circuits. It also allows the IHU to get extensive telemetry data from the PSU including parameters such as the solar panel voltage, battery voltage and battery current.

Cells per unit	18
Nominal voltage	27 V
Nominal capacity: Min.	14.0 Ah
Typical capacity	20.5 Ah
Charge method - Constant current	1 +/- 0.2 A
Max. charge voltage	35.8 +/- 0.15 V
Min. discharge voltage	20.5 +/- 0.5 V
Full charge/discharge circles	5
Temperature range	+6 to +45 C
Min. pressure	1.33 x 10-6 Pa
Wet life	1 year

Figure 6: Battery Specifications.

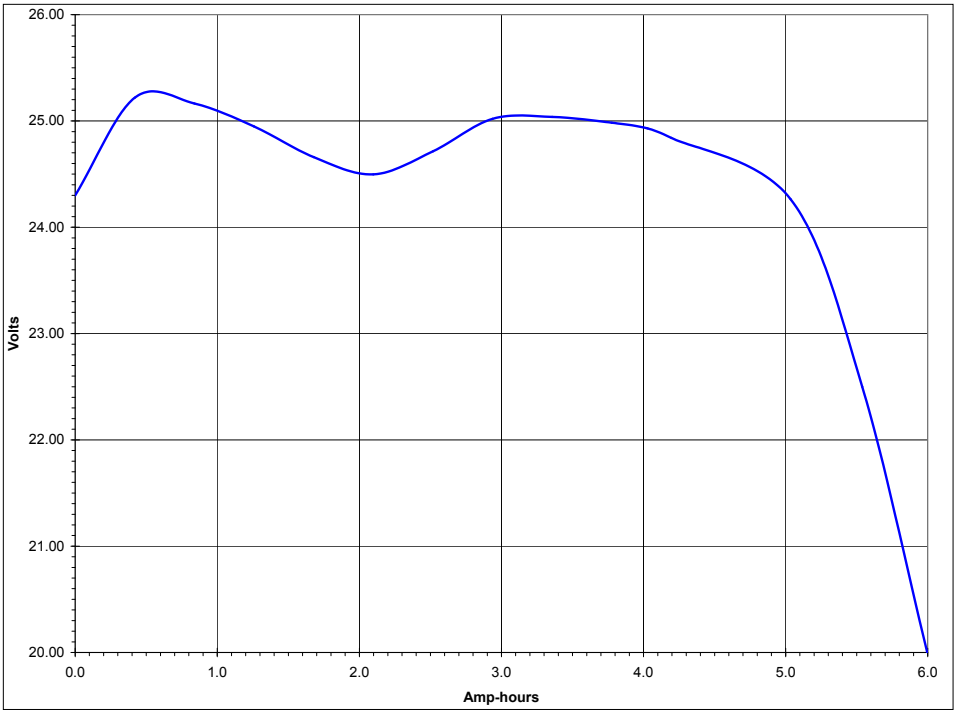

Figure 7: Battery Discharge at -30 degrees C.

The satellite circuits can be grouped into four basic subsystems. These are the IHU, Camera, Experiment, and Transmitter. The IHU subsystem includes the IHU microcontroller, the uplink receivers and the command decoder circuits. These are the basic circuits needed to operate and have control of the satellite. The Camera subsystem is powered whenever a new image is to be acquired from one of the 4 SSTV cameras. The Experiment subsystem is enabled to operate the Kursk science experiment. And the Transmitter function, which includes the Software Defined Transponder (SDX,) is enabled to operate the RF downlinks. In normal operation, the IHU is always turned on and the Camera, Experiment and Transmitter are turned on or off by commands from the IHU.

The current and power required to operate each subsystem is shown in Figure 9. This chart shows the current and power drawn from the 28V bus by the PSU. As can be seen, they depend on the actual bus voltage.

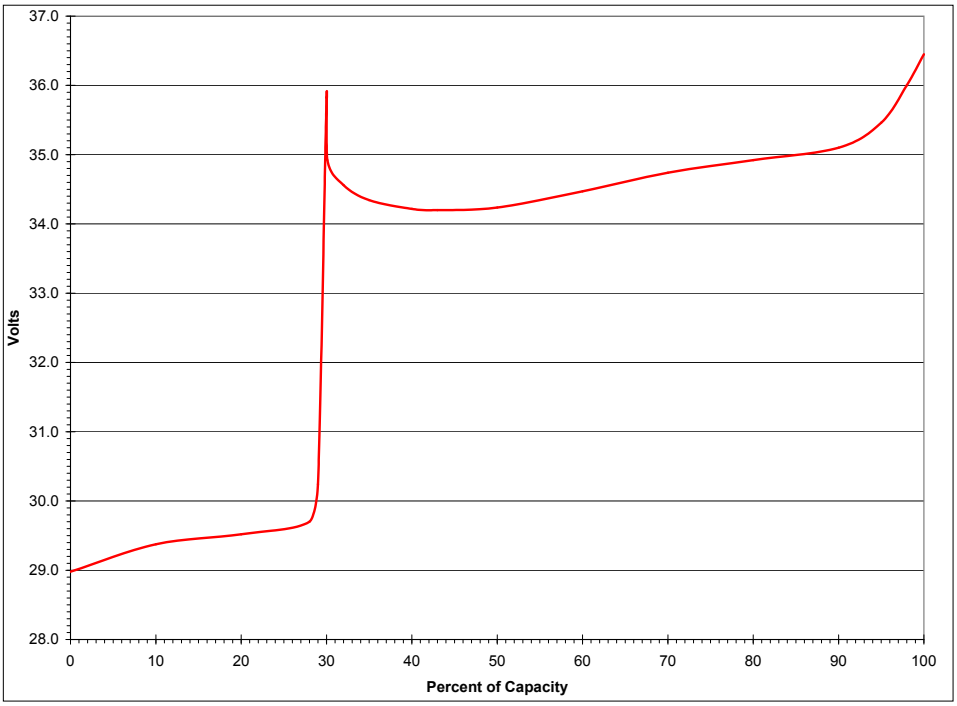

Figure 8: Battery Charge Curve.

Since the IHU normally runs all the time, its average power requirement is the same as what is shown in the chart. The Camera subsystem however, is only turned on briefly to capture and send a new SSTV image and the average power needed is actually quite low. Similarly, the Experiment runs for 100 minutes at a time but only once per day and so its average power over 24 hours is also quite low. The transmitter has the largest power requirement of the satellite and so is the primary means used to manage the overall power usage.

Power Management Software

ARISSat-1 autonomously manages it own power via software running on the IHU. This software gets data from the PSU to determine the power system state. The software sends commands to the PSU to turn on or off satellite subsystem circuits to manage the available power. This software implements an algorithm that balances the need to preserve the life of the battery and prevent power-down in eclipse with maximizing the useful functionality of the satellite. There are three power modes defined; HIGH, LOW and EMERGENCY.

In sunlight and for most solar (beta) angles, the solar panels provide enough power to operate all of the electronics and charge the battery. As long as the battery charge level is adequate, the satellite will switch to HIGH power mode in sunlight. In this mode, all of the satellite functionality is operational including the SSTV cameras and Kursk experiment. All RF downlinks including the mode U/V transponder will be active.

When the solar panels do not provide enough power, such as when the satellite goes into eclipse, the battery must supply some or all of the power. When this condition is detected, the satellite will switch to LOW power mode which will reduce the discharge current from the battery and help to extend the battery life. In this mode, the SSTV cameras will not operate although pre-stored SSTV images will still be sent on the FM downlink. The experiment needs to run for a full orbit including eclipse and so will continue to operate if it is collecting data.

Most of the power savings in LOW power mode is achieved through controlling the RF transmitter. There is no way on ARISSat-1 to vary the amount of power required by the transmitter, only to turn it on or off, so power cycling is employed. The transmitter will be turned on to send telemetry or experiment data on the BPSK downlink which is about

Bus Voltage	IHU		Camera		Experiment		Transmitter	
	mA	watts	mA	watts	mA	watts	mA	watts
24 V	112	2.7	62	1.5	26	0.6	199	4.8
29 V	98	2.9	52	1.5	21	0.6	162	4.7
34 V	91	3.1	47	1.6	21	0.7	142	4.8
36 V	89	3.2	46	1.6	21	0.7	131	4.7

Figure 9: Subsystem Power.

30-40 seconds. After the data is sent, the transmitter will be turned off for 2 minutes. In this way, telemetry and experiment data can be collected by ground stations but the average power needed is significantly reduced. When the transmitter is turned on, all of the RF downlinks will be active including the mode U/V transponder and it will still be possible to make ham radio contacts, albeit with short exchanges.

If the software detects that the battery is dangerously low, the satellite will switch to EMERGENCY power mode. This mode is intended to extend the life of the satellite as much as possible when potential battery failure is imminent. In this mode, the SSTV cameras and experiment are turned off. The transmitter will send just telemetry data on the BPSK downlink which takes about 30 seconds. After the data is sent, the transmitter is turned off for 5½ minutes. This provides ground stations the opportunity to capture 1 or 2 telemetry frames per satellite pass while minimizing the power used. When the transmitter is on, all of the RF downlinks are active including the mode U/V transponder as it does not draw any incremental power. It should still be possible to make ham radio contacts in this mode although the low duty cycle may make it quite difficult.

Energy Balance

As ARISSat-1 orbits the earth, it will be in the sun for 53 minutes and in eclipse for 37 minutes. The satellite consumes energy over the complete orbit but the solar panels only generate it while in the sun. The total energy generated during the time the satellite is in the sun must be greater than the total consumed over the entire orbit to assure that the satellite does not power down when it is in eclipse. This is called having a positive energy balance.

Calculating the energy balance is complicated as there are many factors that affect it. The power consumed depends upon the bus voltage. The power management software changes the power consumption. The power generated by the solar panels and MPPTs depends upon the sun angle and the satellite spin. The MPPT and battery efficiencies are also involved. A model was developed to calculate the effects of all of the factors and predict the energy balance for satellite spin periods within the expected range. The results are shown in Figure 10. The solid line on the chart shows the total energy that can be generated over one orbit and the dashed line shows the energy consumption. As can be seen on the chart, ARISSat-1 should always have a positive energy balance as long as the battery is functional.

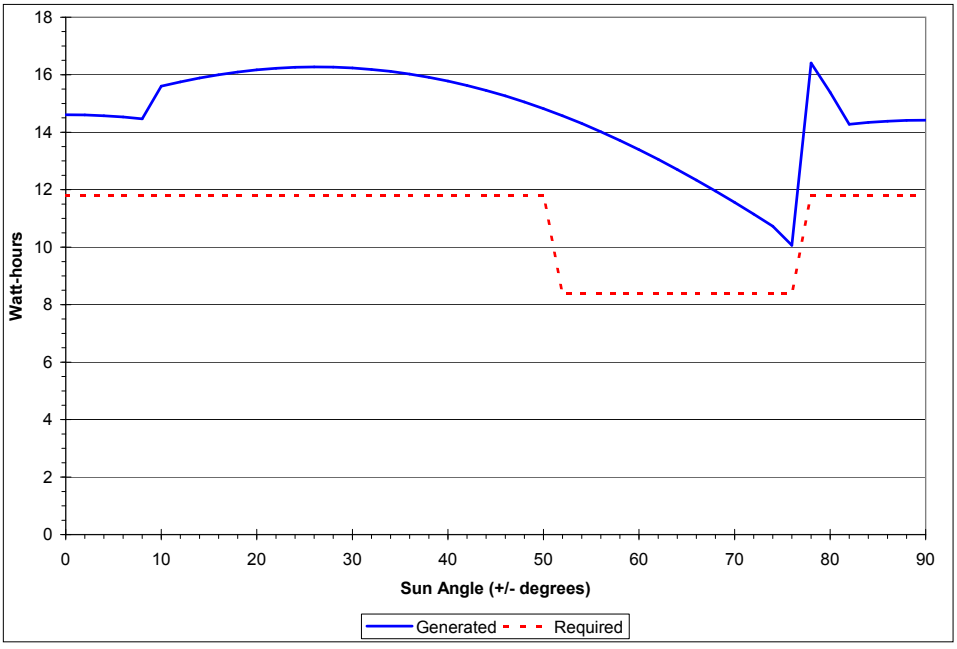

Figure 10: Energy Balance.

Summary

ARISSat-1 generates all of its power from the sun. It has six solar panels that each drive their own maximum power point tracker circuit. In sunlight these power the satellite and charge the battery. In eclipse the satellite is powered by the energy stored in the battery.

ARISSat-1 automatically manages its own power to maintain a positive energy balance and to promote extending the life of its battery. In general, it will operate with full functionality while in sunlight. In eclipse, it will cycle the RF transmitter to reduce the power consumption. Should the battery charge go too low, it will drop the power usage to a minimum to extend the life as long as possible. Based on the planned power modes, the battery is estimated to maintain nominal operation for at least 2 months with a positive energy balance and should continue to operate in some capacity until the satellite reenters.

Notes

[1] *SMEX-Lite Modular Solar Array Architecture,* by John W. Lyons, NASA Goddard Space Flight Center, Code 563, Greenbelt, MD 20771 (IECEC2002)

[2] *Statement of Work for the SMEX-LITE Modular Solar Array Panels,* NASA, Goddard Space Flight Center, Greenbelt, MD 20771

[3] The satellite was originally named *SuitSat-2* and was based on a Russian space suit.

[4] 825M3 Accumulator Battery Specification provided by RSC-Energia via Lou McFadin, 1/16/2010

[5] Private email and phone conversations with the staff of Yardney Technical Products.

[6] *Survey of Rechargeable Battery Technology, Report to Lawrence Livermore National Laboratories,* by A.D. Little, Inc. Cambridge, MA 1993.

[7] *Battery Definition for the MARS Environmental Survey Mission (MESUR) Pathfinder*, by S. Dawson, D. Perrone, B. Otzinger, S. Di Stefano, Jet Propulsion Laboratory, California Institute of Technology 1994.

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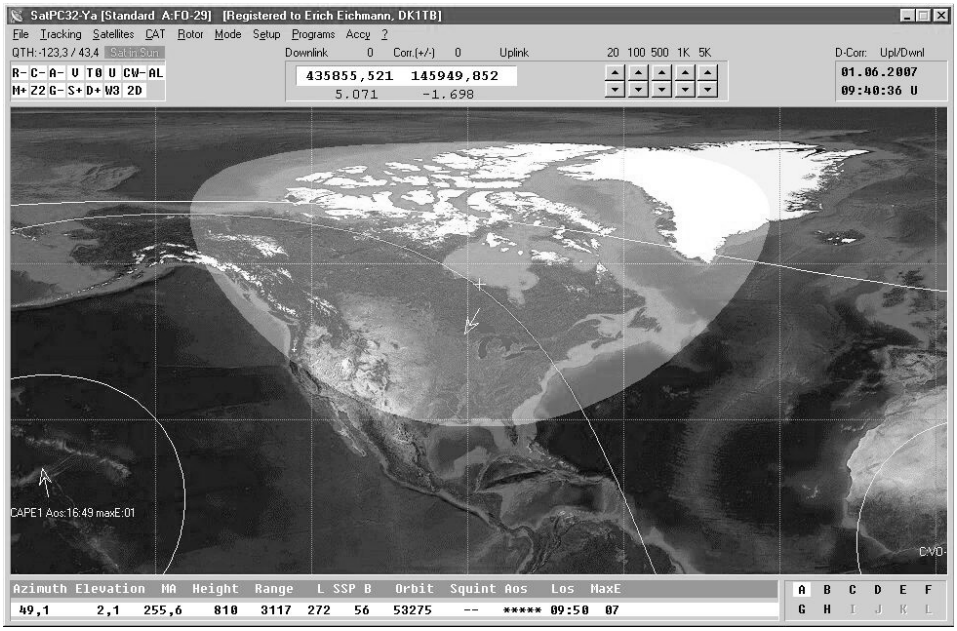

AO-51 Battery Capacity and Spin Trends

by Mark Hammond, N8MH, n8mh@amsat.org
and Colin Hurst, VK5HI, vk5hi@amsat.org

Introduction

Trends that have been of ongoing interest to the AO-51 Operations Group are those of battery voltage, battery capacity, spin rate and temperatures. This paper outlines the long-term trends that have been noted for battery capacity and spin rate, tabulated since 1 January 2005.

Historical Clarifications on AO-51

Since the launch of AO-51 in June 2004, the various command stations that have been given the responsibility to maintain its longevity have been involved in continuous monitoring and analysis of the real-time telemetry and the whole orbit data (WOD). There have been periods when this has necessitated daily analysis and modification of on-board parameters.

In August 2006 a series of tests were conducted to clarify a number of concerns with respect to the performance of AO-51. One conclusion that was drawn at that time was that Radio Frequency Interference (RFI) from the Mode U Transmitters was affecting the performance of the Battery Control Regulator (BCR). Since August 2006, the BCR performance appears to have deteriorated further, which has resulted in a level of overcharge of the batteries. The BCR issue, coupled with the total illumination periods that have occurred during 2008, 2009 and 2010, have required numerous innovative approaches on behalf of the command stations to maintain continuous operation of AO-51. It is not the intention of this paper to elaborate on those procedures, but to identify the trends since January 2005. The trends have been compiled using the WOD's from AO-51. Since November 2006, the WOD's have been scheduled on an almost daily basis. Generally the WOD's are collected using 5, 30 or 60 second sampling periods.

Battery Capacity

The battery pack on AO-51 consists of six 1.2 volt, 4 ampere-hour Ni-Cd cells. On advice, AO-51's command stations have only cycled AO-51's batteries on the float charge section of a Ni-Cd charge/discharge curve. That is from a nominal 1.2 volts to the maximum charging voltage.

With reference to Figure 1, which shows the battery discharge profile on 16 January 2005 during an eclipse of 32 minutes duration, we can make a number of observations.

- Cells 1, 2, 3 and 4 demonstrate similar discharge capacity
- Cell 5 appears to demonstrate a higher capacity
- Cell 6 appears to be an under-performing cell

One may argue that the calibration of the various cells was not optimal (an argument that has been previously raised), however for the purpose of this paper it is accepted that the respective voltage and current calibration values were correct at launch.

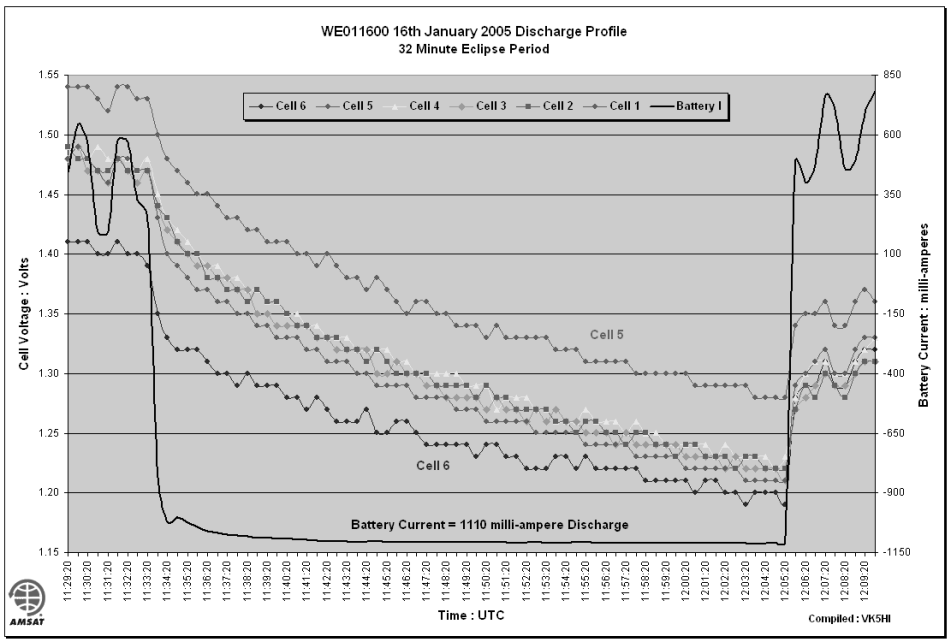

Figure 1

Battery Capacity

See Figure 1.

To describe past battery discharge trends we will use the energy term joule. One joule = one watt-second. Battery voltage is not a true indicator of the health of a battery, whereas if we use discharge energy we can truly represent the health of the battery.

The discharge energy (capacity) can be readily calculated from the WOD's, using the procedure outlined in Appendix A. All the values quoted throughout this paper have used this procedure.

Using the WOD, we011600 of 16 January 2006 from which Figure 1 was derived, we can make the following calculation to ascertain the maximum available capacity:

At the time of entering eclipse the total battery voltage was 8.81 volts.

The battery was fully charged, because of the ongoing BCR issue.

From the following calculation we note that the available discharge capacity is 21,100 joules.

The calculation is the average of the cell voltages (8.81 / 6) multiplied by the battery capacity in ampere-seconds (4 AH x 3600 seconds) = 21,100 joules.

Later in this paper we will highlight that the total discharge during this 32 minute eclipse period was 15,587 joules.

Battery Capacity

Now we will advance five and a half years to 9 May 2010.

During that five and a half year period, AO-51 has endured 3 total illumination periods.

They were from 5 January 2008 to 9 April 2008, approximately 3 months. Then from 18 August 2008 to 7 May 2009 a period of 9.5 months. Finally 30 July 2009 to 30 April 2010, a period of 9 months. From 5 January 2008 to the 30 April 2010, AO-51 was totally illuminated for 21.5 months out of 28 months, 77% of that period.

Fortunately (from a telemetry point of view) AO-51 encountered a low-voltage trip at 00:06 UTC on 10 May 2010, (during an 8.4 minute eclipse period), which has

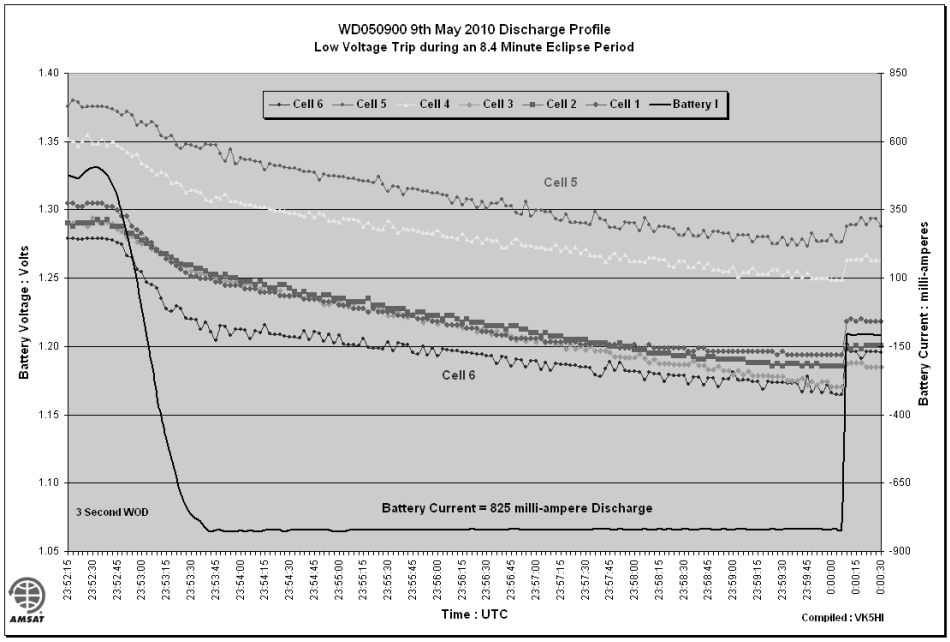

Figure 2

allowed the calculation of a definitive battery capacity (following the third total illumination period).

See Figure 2 which highlights the low-voltage trip at 00:06 UTC.

Fortunately this graphic (obtained from a 3 second WOD) allows us to calculate the battery capacity with a high level of confidence.

At the point of entering the eclipse period the maximum battery voltage was 7.87 volts as compared to 8.81 volts in January 2005, which indicates a degree of degradation of all the six Ni-Cd Cells.

Battery Capacity

Observations from Figure 2 include:

- Cells 1, 2 and 3 have degraded to a greater extent than Cell 4.
- Cell 5 although degraded still demonstrates a higher capacity relative to the other cells
- Cell 6 continues to be the under-performing cell.

Calculation of the effective maximum battery capacity from the WOD data WD050900, amounts to a value of 2500 joules. This was calculated from the point of entering the eclipse period until the low-voltage trip occurred. This calculation is per the procedure outlined in Appendix A.

All the WOD's are available for download per Bibliography Note 3 should you wish to do follow-up analysis.

Hence we have degradation over five and half-years from a nominal capacity of 21,100 joules to 2,500 joules. This means that as of 9 May 2010 we only had 12% of the original battery capacity.

Now we will review the historical trends over the 2005 to 2010 period.

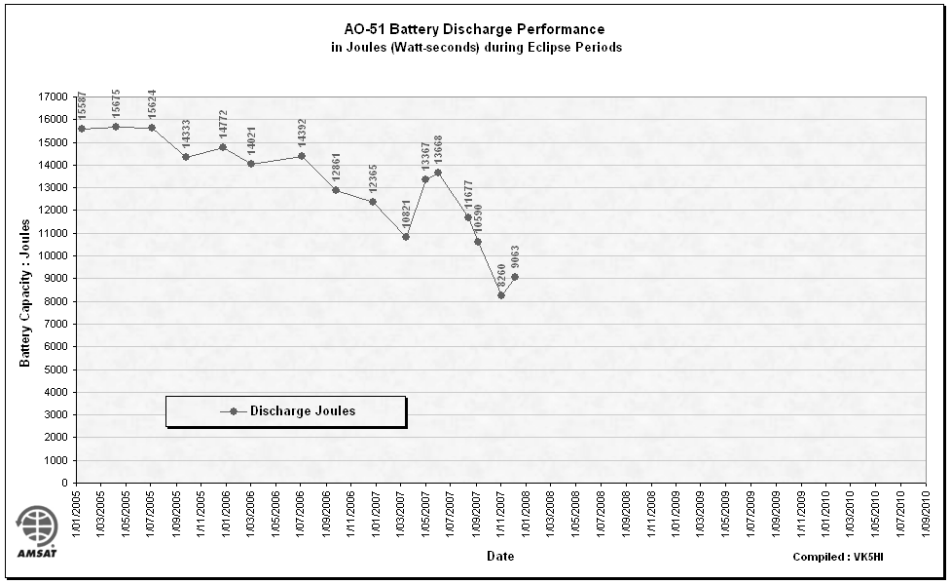

Figure 3

Historical Battery Discharge Trend

To explain the historical trend of actual battery discharge, we will present the data in 3 stages.

Prior to the total illumination periods, inclusive of the total illumination periods, and finally one of the battery status as of 9 May 2010.

Prior to Total Illumination Periods

Figure 3 highlights the period prior to the total illumination periods.

Looking at this graphic a question arises. What is the trend of the discharge curve?

- During the period 2005 to 2007, the command stations experimented with different power budget scenarios to ascertain the optimal operating parameters for AO-51. Of paramount importance was the battery performance.
- The "humps and bumps" are the result of the command station experimentation. The objective being optimal downlink power while maintaining a safe level of battery voltage.
- The net downward trend of the graphic is clear, and approximates to a second order polynomial, shown later in this presentation.

Historical Battery Discharge Trend

- Inclusive of the Total Illumination Periods

Figure 4 includes the three total illumination periods that occurred in 2008, 2009 and 2010.

At the conclusion of the total illumination period #1 in 2008, the command stations became acutely aware of a level of degradation of the battery capacity. The maximum capacity available during the following eclipse periods was nominally 9,700 / 9,800 joules, compared to 21,000 in January 2005. A reduction of 55%.

At the conclusion of the total illumination period #2 of 2008/2009, a further level in battery capacity was noted. Empirical data obtained from the WOD's indicated that the battery capacity had reduced to 6000 / 6800 joules. Compared to January 2005 a total

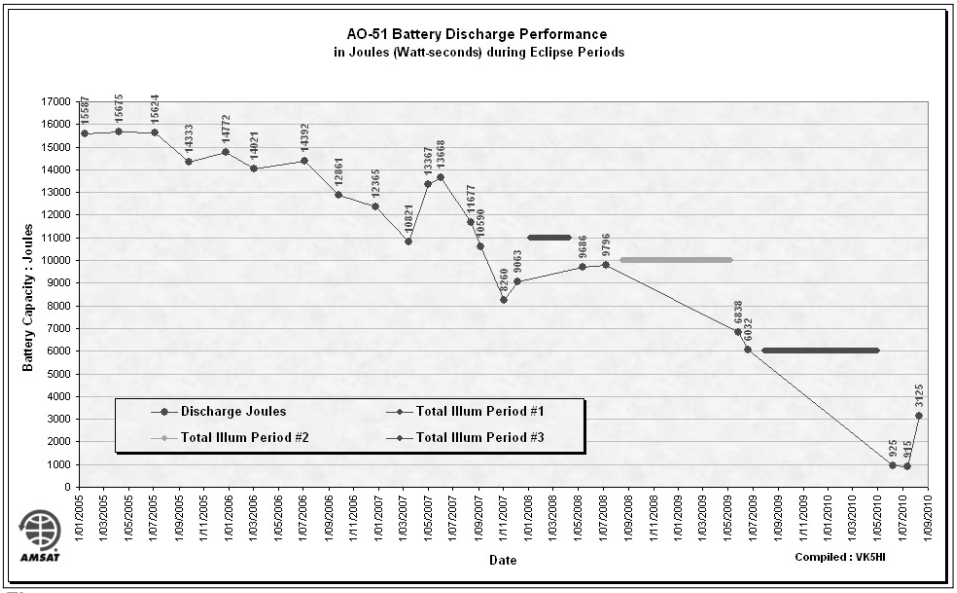

Figure 4

reduction of 70%.

In both of the above observations the battery discharge values are the result of the command stations setting what they consider to be the safest and optimal parameters for AO-51.

At the conclusion of the total illumination period #3 of 2009/2010 the battery capacity had degraded to a level that transmit operations during increasing eclipse periods were not practicable.

The nominal 925 joule discharges shown for 8 June and 15 July 2010 is to maintain the CPU during 20 minute eclipse periods.

Historical Battery Discharge Trend

Battery Status as of 9 May 2010

As stated previously it was fortuitous AO-51 encountered a low-voltage trip at 00:06 UTC on 10 May 2010, which has allowed the calculation of a definitive battery capacity of 2500 joules. This is shown in Figure 5. A battery capacity of 2500 joules is totally inadequate to run a transmitter during an extended eclipse period. 2500 joules is 12% of the battery capacity as of 16 January 2005.

A learned member of AMSAT-NA expressed an opinion some time ago that he believed the batteries may recover when lower temperatures were experienced once out of the total illumination periods. Due to a software anomaly on 11 August 2010 with the Power Management System, AO-51 operated at low power (420 milliwatts) during the eclipse periods on that day, without a low voltage trip. This event allowed another definitive calculation of the battery capacity, with a result of 3125 joules. This suggests an improvement from 2500 joules on 10 May to at least 3125 joules, which is a 25% improvement. In real terms this is not a huge increase in capacity, but was sufficient to allow AO-51 to navigate the shorter eclipse period.

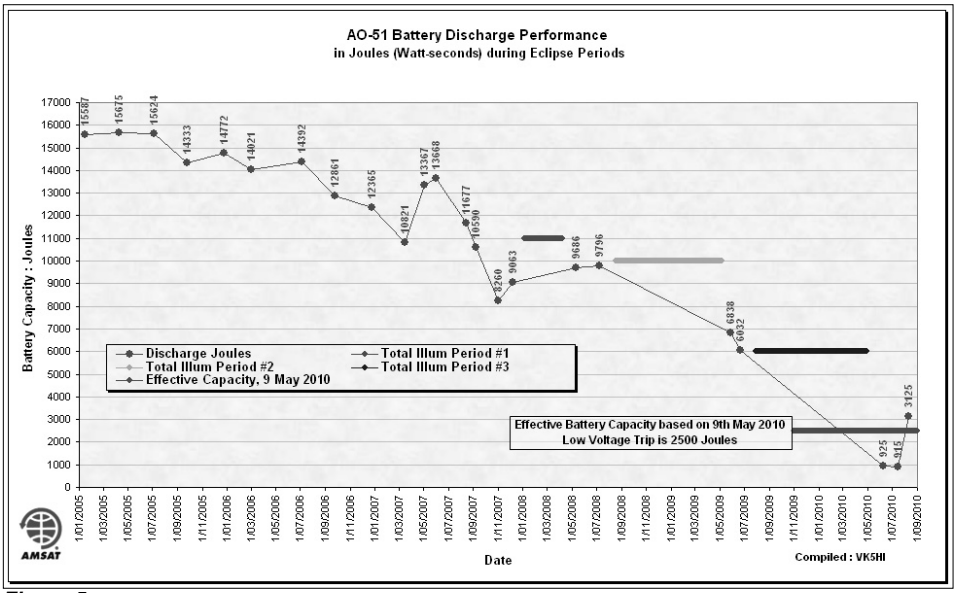

Figure 5

Historical Battery Discharge Trend

Discharge Trend Prediction

Figure 6 demonstrates that the degradation of the batteries has followed a second order polynomial trend.

Total illumination period #4 commenced on 24 August 2010. The cessation of that period will be on 31 December 2010.

Clarification

It is not the intention of the authors to advance any substantive theory as to why the battery capacity has degraded to the current low levels apart to note that heat may have been one of the contributing factors.

We have not advanced any discussion on the charging capacity of the batteries, because of the BCR issue mentioned previously. Although work has been carried out on charging capacity the results are somewhat ambiguous and would not contribute positively to this presentation.

Spin Trends

Period 25 July 2004 to 2 December 2009

The spin period/spin rate has been of significant interest to the AO-51 Operations Group and Alan Biddle, WA4SCA.

When AO-51 was launched in July 2004 the spin rate was nominally 2.5 RPM. After approximately three and a half years the spin rate commenced to decrease viz: the spin period increased. Figure 6 highlights the spin period from 25 July to 2 December 2009.

Please see Figure 7.

From Figure 7 the following observations can be made:

- From July 2004 to January 2008 the spin period remained relatively constant at 0.4 minutes which equates to 2.5 rpm
- From January 2008 there is a gradual increase in the spin period.
- During 2009 the spin period escalated significantly. On 2 December 2009 the rotation speed of AO-51 was 0.03 rpm

When satellites are placed into orbit, they have a pre-determined level of spin to ensure that the designed thermal cooling of the satellite is maintained. Hence, the downside of the slowdown in AO-51's rotational speed is that the ability to maintain the designed cooling is diminished.

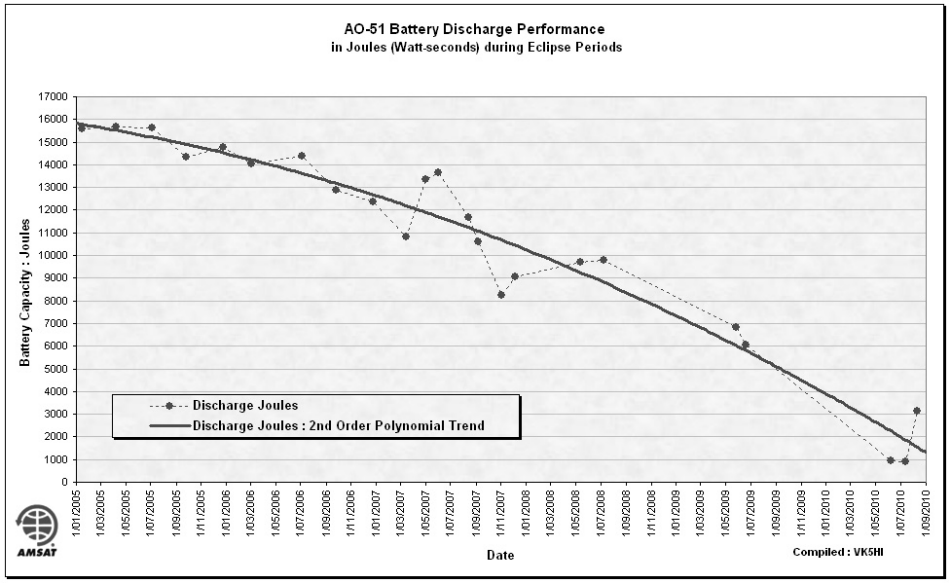

Figure 6

Spin Trends

1 December 2009 to 13 February 2010

Figure 8 identifies the spin period profile following the flip experiment.

On 2 December 2009, AO-51 was commanded to flip, such that AO-51's Mode V and U antenna favored the southern hemisphere. Prior to the flip experiment Tom Clark, K3IO, [2] mailed a note on 2 December 2009 to the AO-51 Operations Group that in part said:

"Since angular momentum must be conserved when you "flip" the s/c, the s/c body should precess (probably looking like tumbling) until the momentum dampers absorb the change. Keep an eye on the solar panel currents and I'll bet the spin rate will change".

Spin Trends

1 December 2009 to 13 February 2010

- From Figure 8 we can clearly observe that the spin period did indeed fluctuate. Following the flip command the spin period tended towards the launch value on 4 December 2009.
- After 4 December the spin period then continued to increase such that it peaked on 19 December at 57.8 minutes and a spin reversal took place such that AO-51 began spinning in the opposite direction as confirmed by observations of solar panel current data.
- On 9 January 2010 a second flip command was sent to AO-51 to revert back to its normal attitude. It was also recorded that AO-51 reverted back to its normal spin sequence.
- After the second flip command the spin rate reduced for a short period prior to levelling out.
- The spin reversal generated a significant level of interest. Alan, WA4SCA, drew the group's attention, to documentation by Doug Sinclair [1], in which Doug discusses the issue of spin reversal. The reversible permanent magnet Torque Rod on AO-51 is very similar to that covered in Doug's documentation.

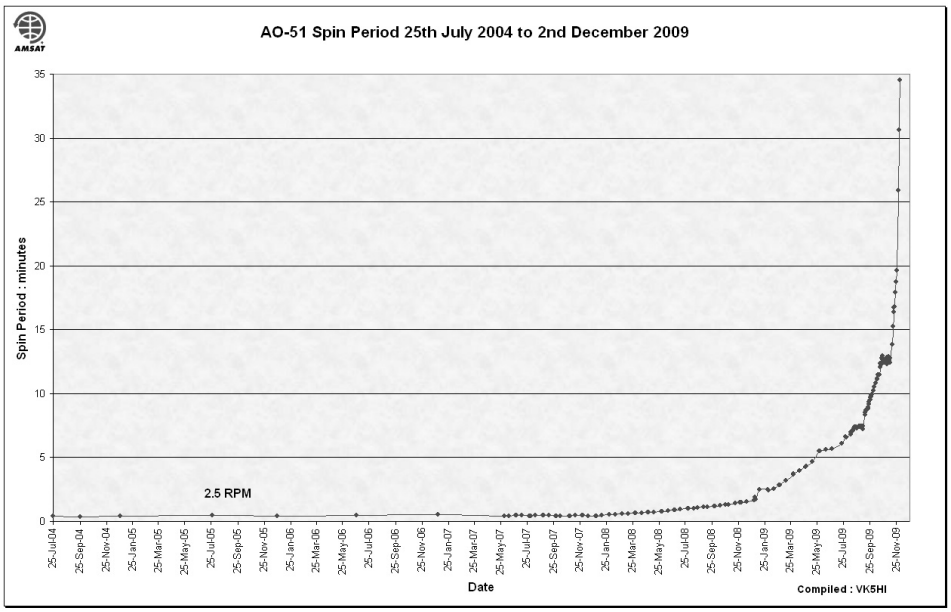

Figure 7

Spin Trends

1 December 2009 to August 2010

Figure 9 highlights that after some months from the second flip command (issued to return the spacecraft's mode U and V antenna to again favor the northern hemisphere), AO-51 has stabilized at a nominal spin period of 7.5 minutes, which is a rotational speed of 0.13 rpm.

Prior to the flip commands, Alan Biddle, WA4SCA, had also been monitoring the spin period for a considerable period of time. Alan mounted an excellent argument that perhaps the black and white Kapton tape used to maintain a spin component on AO-51, had deteriorated.

In Tom Clark's mail [2] previously quoted, he also made the following comments with respect to spin.

"My guess is that the momentum loss is due to eddy currents induced in the s/c body by the earth's magnetic field. Sometime drop a piece of (non-magnetic) aluminum into the poles of a big magnet -- you'll see the aluminum change speed noticeably. Back in the antique days of mechanical speedometers in cars, the speedo cable turned a permanent magnet above an aluminum or brass disk connected to the indicator. As the magnet spun faster, eddy currents would drag the disk/pointer to higher values."

The stabilization of the spin period since the flip experiment tends to suggest that the Kapton tape remains intact and that Tom's guess may have been correct.

Conclusions

This paper covers many hours of telemetry analysis and as such is just an overview of many observations. Follow-up can be made to the authors.

Bibliography

[1] Flight Results from a Novel Magnetic Actuator on the LatinSat Spacecraft, Doug Sinclair and Dr. Chris Damaren,

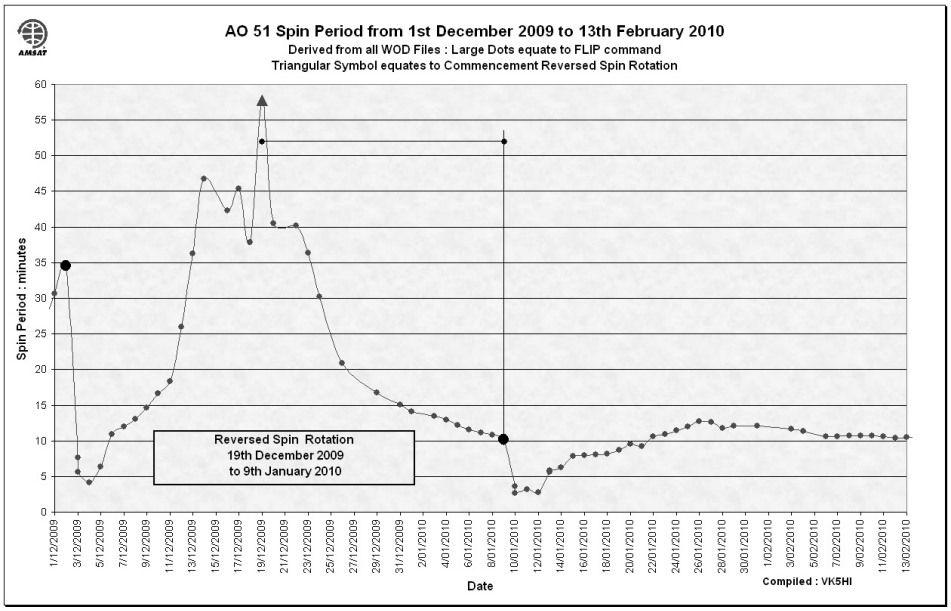

Figure 8

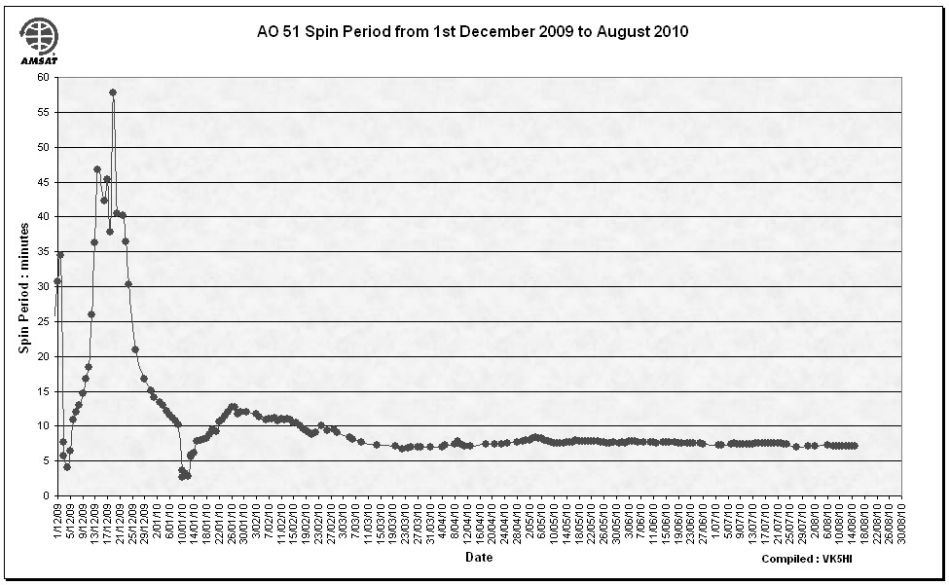

Figure 9

http://www.sinclairinterplanetary.com/publications

[2] Tom Clark, e-mail to AO-51 Operations Group, 2 December 2009.

[3] AO-51 WOD Archive is obtainable from **ftp://ftp.amsat.org/amsat/telemetry/ao51/**

Appendix A: Calculation of Discharge Capacity

The whole orbit data (WOD) from AO-51 is stored then downloaded in a pre-defined format with a filename WDmmddnn, where mm is Month, dd is Day and nn is filenumber. Software is available that converts these files to a Microsoft Office .csv file, for analysis.

Prior to a software change, when more telemetered channels were added, the WOD's were labelled WEmmddnn. WOD's are generally of 5, 30 or 60 second sampling periods, however any sampling period can be programmed. Suffice it to say the WOD's contain substantive performance information about AO-51.

The spreadsheet segment detailed on the next page has been cut and pasted from the analysis of we070501, 5 July 2006. This WOD has been chosen as it has 60 second sampling.

By explanation Column 1 is the time.

The actual WOD voltages are such that they are the summation of Cells 1 to 6, Cells 1 to 5 etc.

Columns 2 through 7 show the individual cell voltages, calculated from the telemetered WOD values.

Column 8 shows the telemetered battery current. The section highlighted in **bold type** is the eclipse period being analyzed.

Column 10 is the sum of the individual cell voltages (columns 2 through 7) for the **eclipse period,** i.e., when the battery current is negative.

We have defined battery capacity in joules, where one joule is one watt-second.

AO-51's bus structure being direct current (DC) allows us to use simple mathematics to calculate of battery capacity in joules, from the WOD information.

joules = watt–seconds

Battery discharge joules = battery voltage (multiplied by) battery discharge current in milli-amperes (divided by) 1000 (multiply) sampling period in seconds.

joules = V x I (ma) / 1000 x seconds.

Column 10 shows the calculation of the discharge joules using the above formula for each sampling period of 60 seconds.

The value at the bottom of column 10 (-14392.93) is the sum of the discharge capacities. This is the value shown in Figure 5, for 5 July 2006.

The average battery voltage at the bottom of column 9 is a reference value used for a different analysis set.

Prepared by Colin Hurst, VK5HI, 5 August 2010.

Whole Orbit Data Extracted from the Analysis of we070501

Echo Time	Cell 6	Cell 5	Cell 4	Cell 3	Cell 2	Cell 1	Battery I	Battery V	Joules
17:46:26	1.42	1.54	1.50	1.47	1.48	1.48	583.59		
17:47:26	1.41	1.54	1.49	1.47	1.48	1.47	328.00		
17:48:26	1.42	1.54	1.50	1.48	1.48	1.48	249.36		
17:49:26	1.43	1.54	1.50	1.48	1.49	1.48	591.45		
17:50:26	1.35	1.51	1.44	1.44	1.44	1.42	**-917.77**	8.60	-473.57
17:51:26	1.33	1.48	1.42	1.41	1.41	1.39	**-953.27**	8.44	-482.74
17:52:26	1.32	1.45	1.41	1.39	1.40	1.37	**-972.99**	8.34	-486.88
17:53:26	1.30	1.45	1.39	1.38	1.38	1.36	**-984.82**	8.26	-488.08
17:54:26	1.30	1.43	1.38	1.37	1.37	1.35	**-988.77**	8.20	-486.47
17:55:26	1.29	1.42	1.37	1.35	1.37	1.34	**-988.77**	8.14	-482.92
17:56:26	1.29	1.41	1.36	1.34	1.36	1.33	**-992.71**	8.09	-481.86
17:57:26	1.28	1.41	1.35	1.33	1.35	1.32	**-992.71**	8.04	-478.88
17:58:26	1.29	1.39	1.34	1.33	1.34	1.31	**-996.66**	8.00	-478.40
17:59:26	1.28	1.39	1.33	1.32	1.32	1.31	**-996.66**	7.95	-475.41
18:00:26	1.26	1.38	1.33	1.31	1.32	1.30	**-996.66**	7.90	-472.42
18:01:26	1.26	1.37	1.32	1.31	1.31	1.29	**-996.66**	7.86	-470.02
18:02:26	1.26	1.37	1.31	1.30	1.30	1.29	**-996.66**	7.83	-468.23
18:03:26	1.25	1.36	1.30	1.30	1.30	1.28	**-996.66**	7.79	-465.84
18:04:26	1.25	1.35	1.30	1.29	1.29	1.28	**-1000.60**	7.76	-465.88
18:05:26	1.24	1.35	1.30	1.28	1.29	1.27	**-1000.60**	7.73	-464.08
18:06:26	1.24	1.34	1.29	1.28	1.28	1.27	**-1000.60**	7.70	-462.28
18:07:26	1.24	1.33	1.28	1.28	1.28	1.26	**-1000.60**	7.67	-460.48
18:08:26	1.24	1.33	1.28	1.27	1.27	1.26	**-996.66**	7.65	-457.47
18:09:26	1.23	1.33	1.27	1.27	1.27	1.25	**-1000.60**	7.62	-457.47
18:10:26	1.23	1.32	1.27	1.26	1.26	1.25	**-996.66**	7.59	-453.88
18:11:26	1.23	1.31	1.27	1.26	1.26	1.24	**-1000.60**	7.57	-454.47
18:12:26	1.22	1.31	1.27	1.24	1.26	1.24	**-996.66**	7.54	-450.89
18:13:26	1.21	1.31	1.26	1.25	1.25	1.23	**-1000.60**	7.51	-450.87
18:14:26	1.21	1.31	1.25	1.24	1.25	1.23	**-1000.60**	7.49	-449.67
18:15:26	1.22	1.30	1.24	1.24	1.24	1.23	**-1000.60**	7.47	-448.47
18:16:26	1.20	1.30	1.24	1.23	1.24	1.22	**-1000.60**	7.43	-446.07
18:17:26	1.21	1.29	1.24	1.23	1.23	1.22	**-1004.54**	7.42	-447.22
18:18:26	1.21	1.28	1.24	1.22	1.23	1.21	**-1004.54**	7.39	-445.41
18:19:26	1.21	1.28	1.23	1.22	1.22	1.21	**-1004.54**	7.37	-444.21
18:20:26	1.20	1.28	1.22	1.21	1.22	1.21	**-1004.54**	7.34	-442.40
18:21:26	1.29	1.34	1.29	1.29	1.28	1.30	646.50	Avg Volts	Sum J
18:22:26	1.29	1.34	1.30	1.28	1.29	1.30	559.99	7.80	-14392.93
18:23:26	1.30	1.35	1.32	1.28	1.30	1.31	674.02		
18:24:26	1.30	1.35	1.31	1.29	1.29	1.30	434.17		
18:25:26	1.32	1.38	1.33	1.31	1.31	1.33	544.26		
18:26:26	1.32	1.38	1.34	1.31	1.32	1.33	697.62		
18:27:26	1.32	1.38	1.34	1.31	1.32	1.33	721.21		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

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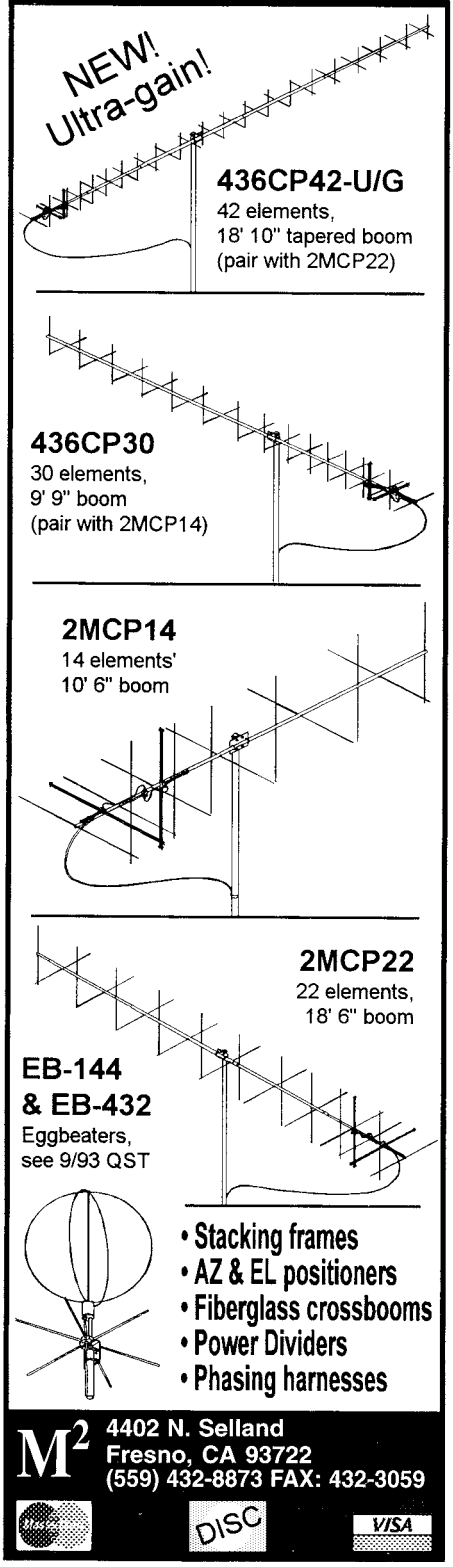

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DISC VISA

Apogee View - continued from page 3 ...

the NASA Office of Education has been instrumental in the overall effort. For example, formal protocols outlining roles/responsibilities of AMSAT, RSC-Energia and NASA were drafted by Mark Severance, N5WXF, ISS National Laboratory Education Projects Manager to ensure mutual agreement on the scope of the project. NASA personnel provided key support and guidance in the Payload Safety Review Panel (PSRP) process as ARISSat-1 went through a rigorous 3-phase technical review that took over six months. While AMSAT provided the technical information, we were guided by NASA's Mark Steiner, K3MS, and Mark Severance, N5XWF, along with Claire Fredlund of Orbital/ Technical Services Division in Greenbelt, MD (who prepared the PSRP reports and presentations). Endorsement through the PSRP was essential since ARISSat-1 would not be allowed on the ISS without gaining these approvals.

In addition, through Mark Severance's efforts, NASA provided critical support for the export process to Russia, including gaining appropriate export licensing as well as arranging for transportation from the US to Russia. Having become very familiar with ITAR over the last two years, we are very sensitive to following the rules. By having direct NASA involvement our project benefited in several ways. First, all technical discussions were under the NASA-RSC-Energia Technical Assistance Agreement (TAA), which meant that NASA employees were involved with all telcons and e-mail exchanges involving foreign nationals. AMSAT did not have to have our own TAA with RSC-Energia. Second, NASA handled the export licensing process for ARISSat-1, removing a significant administrative and legal expense for AMSAT. Third, AMSAT shipped ARISSat-1 to the NASA Johnson Space Center in Houston and NASA subsequently arranged and paid for shipping to Moscow, saving AMSAT considerable expense and ensuring a more reliable shipping process as NASA regularly ships materials to Russia and they understand the process better than we do.

The significant impact of two individuals should be recognized. Lou McFadin, W5DID, in many ways is the old salt of ARISSat-1. A key contributor to Amateur Radio in space since the first SAREX (Shuttle Amateur Radio Experiment) in 1983, Lou literally has touched every development concerning Amateur Radio and manned space. He has built countless antennas, interfaces, modules, etc. that have made it possible for Amateur Radio to operate onboard the Shuttle and now the International Space Station. His tireless support of ARISSat-1 is reflected in everything that he has done with the project. Much of the mechanical work building ARISSat-1 was done in his garage. He flew to Moscow in 2008 and in 2010 to support the project. He provided important information this past week to the head of the Energia EVA department at a meeting in Houston conducted by NASA to discuss the deployment of ARISSat-1 (among other subjects discussed). Lou, following procedures established by Bob Davis, KF4KSS, led all of the testing of ARISSat-1 that was done in Orlando. Clearly, ARISSat-1 would not have been completed without Lou's hands-on involvement.

The other key individual is Gould Smith, WA4SXM, who is the ARISSat-1 Project Manager. Gould joined the program in 2008 to establish an improved project management function and to get the team working more closely as a team. This wasn't easy given the wide geographical dispersion of our volunteers and the relative lack of prior experience of some team members with large projects involving the unique requirements of building something to survive the rigors of space. What some may not realize is that in many ways, cutting metal or melting solder is not the most difficult part of a project. It is the orchestration of many pieces to ensure that everything is properly designed and planned to come together as expected that can be difficult. Further, given that ARISSat-1 was going to be flown to the ISS, the design standards that had to be followed to meet safety requirements and the documentation necessary to present to the space agencies on the safety of the design and verification of construction was absolutely essential. Gould did a masterful job of helping to shepherd the team through these requirements. He also spent countless hours in Orlando with the final assembly and subsequent vibration and thermal testing of the modules and spacecraft.

Another significant impact of ARISSat-1 is the follow-up AFTER the satellite is deployed. Given the educational thrust of this project, AMSAT is also spending considerable effort to develop awareness within the educational community of the potential for using ARISSat-1 in the classroom and developing materials that would be helpful to educators. A special Web site, *www.arissat1.org*, has been created for educators and others to use as a resource to take advantage of materials developed for use in the classroom. A certified educator, Gould has taken the lead on developing these materials. Lou, Gould and I were interviewed by writers at the NASA Marshall Space Flight Center about ARISSat-1, which we expect will be turned into a Web feature on the NASA Web site shortly after deployment which will also help to build educational awareness. An AMSAT news release on ARISSat-1 developed by David Jordan, AA4KN, has been created for distribution to various media outlets as well, including education outlets. David also authored an article on ARISSat-1, which was featured as the cover story in the February 2011 of QST. Given that the satellite will be in operation for 3-6 months (the exact lifetime being highly dependent on solar activity), it is critical that educators be made aware of the resources available as early as possible so that these resources are used during the current academic year, including ground station software developed by Douglas Quagliana, KA2UPW/5, and Gilbert Mackall, N3RZN, that will be available through the www.arissat1.org Web site upon the ARISSat-1 deployment.

Finally, recognition needs to be extended to George Presley, K4RSV, of Orlando, FL in whose garage the final integration of ARISSat-1 took place (along with the flight backup and two additional space frames). We used George's facility (a separate building that houses George's RF lab and shop) as a testing facility to conduct RF and thermal testing of the ARISSat-1 modules (using an improved vacuum/thermal chamber that was utilized for P3-D module testing) as well as a place for extensive operation of ARISSat-1 to verify performance. Currently AMSAT does not have a lab facility, so having the opportunity to use George's garage was critical to doing the final work on ARISSat-1. Stan Wood, WA4NFY, Joe Armbruster, KJ4JIO, and Dave Jordan, AA4KN, worked long hours to get the satellites assembled there.

By the time you read this column, ARISSat-1 may have been deployed and placed in service. As you follow the news on this satellite and (hopefully) have an opportunity

continued on page 27 ...

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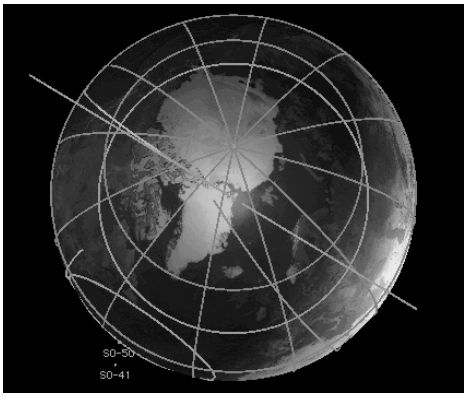

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Confessions of a Helix Junkie, Part 1

by Mike Williams, K9QHO, k9qho@arrl.net

"There it sits in all its splendor simply because, I'm not a big spender." [1] It begins innocently enough with a decision to homebrew a satellite antenna. It progresses onto the pages of *The Antenna Handbook*. And in the end, these odd antennas then become your back yard conversation pieces. What's amazing is the "N" connector is the only part of the antenna that can't be found at the local hardware store. A helix can be homebrewed at a fractional cost of a commercial antenna. This article is not so much about helix theory but more about helix building.

Helix construction can be straightforward. Compared to a purchased antenna, it will require a much longer build time. Good planning avoids errors and obstacles. What is readily available? What can be used for a boom? What can be used for the spreaders? What can be used for the helix? What can be used for the reflector? How does it go together? Is it too heavy? Must it be supported in the middle or can it be end mounted? Is a counterbalance needed? What are the tips? These and more questions will be addressed but first the formulas [2]. The most important answers are below with example calculations for 436 MHz in inches and (meters). Table 1 gives the builder an idea of a helix's dimensions required at each satellite frequency [3].

1. Wavelength (λ) at the build frequency is: λ = 300 ÷ *f* (MHz) 300/436 MHz = 27.09 in. (.688m)
2. Circumference of helix at 436 MHz build frequency: C = λ 27.09 in. (.688m)
3. After finding λ and circumference, helix diameter is: D = C ÷ π .688m/3.14 = 8.62 in. (.219m)
4. S (Turn Spacing): S= C * Tan α (α = normally 12.5 degrees) S = .688m * tan 12.5°= .688 * .2216 =6.02 in (0.15m)
5. L (Length of wire needed for helix, N= Turns, and w = C/cos α): L = Nw + .5 * SqRt ($S^2 + D^2$) L = 15 * .704 + .5 * SqRt (.023 + .048) = 420.99 in. (10.69m)
6. Reflector size = .6λ = .6 * .688m = 16.28 in. (0.41m)
7. Boom Length = λ (N + 0.5)Tan α = .688m (15+0.5)tan 12.5 = 93.1 in. (2.36m)

Table 1: Helix Calculations: inches and (meters)

Freq. MHz	146	436	1269	2401
Turns	6	15	15	15
Circumference/ λ	80.90(2.05)	27.09(0.69)	9.31(0.24)	4.92(0.12)
Diameter	25.75(0.65)	8.62(0.22)	2.96(0.08)	1.57(0.04)
Spacing (@12.5)	17.93(0.46)	6.01(0.15)	2.06(0.05)	1.09(0.03)
Length of Wire	512.86(13.03)	420.99(10.69)	144.80(3.68)	76.53(1.94)
Reflector (.6)	48.54(1.23)	16.28(0.41)	5.58(0.14)	2.95(0.07)
Boom Length	116.57(2.96)	93.09(2.36)	31.98(0.81)	16.90(0.43)

What's Available

PVC, CPVC, square aluminum tubing, fiberglass driveway markers, bicycle flag sticks, wood dowel, aluminum (clothesline) wire, solid copper wire (insulated & non-insulated), ¼ in. copper refrigeration tubing and chicken wire are normally available at the hardware store. When shopping at the big hardware and discount stores, be on the lookout for aluminum pizza pans and grill cooking sheets. For example, AF9Y's 436 MHz helix [4] (Photo 1) was constructed using a 4-in. thin walled PVC drainage tile, ½ in. CPVC for the spreaders, PVC glue, ¼ inch refrigeration tubing, and cable ties.

The Boom

The easy choices are square aluminum tubing or PVC. Square aluminum-tubing boom is a preferred choice for 2 m and 70 cm. It is lightweight, very strong and easy to work with. It's much easier to measure and drill with a square flat surface (Photo 6) rather than round. It is usually available in ¾ or 1 inch at lengths of 6 and 8 ft. With a center punch, drill, a good eye and basic tools a helix can be built. One good quality U-Bolt [5] will secure the boom to the mast.

PVC is inexpensive and commonly found at any hardware store. A helix can be constructed with basic skills, PVC glue and imagination (Photo 2). PVC can be drilled and tapped allowing sections to be held together with screws instead of glue. Typical tools are a center punch and drill press. A drill press is recommended to assure proper placement and alignment of the spreader holes in a round boom.

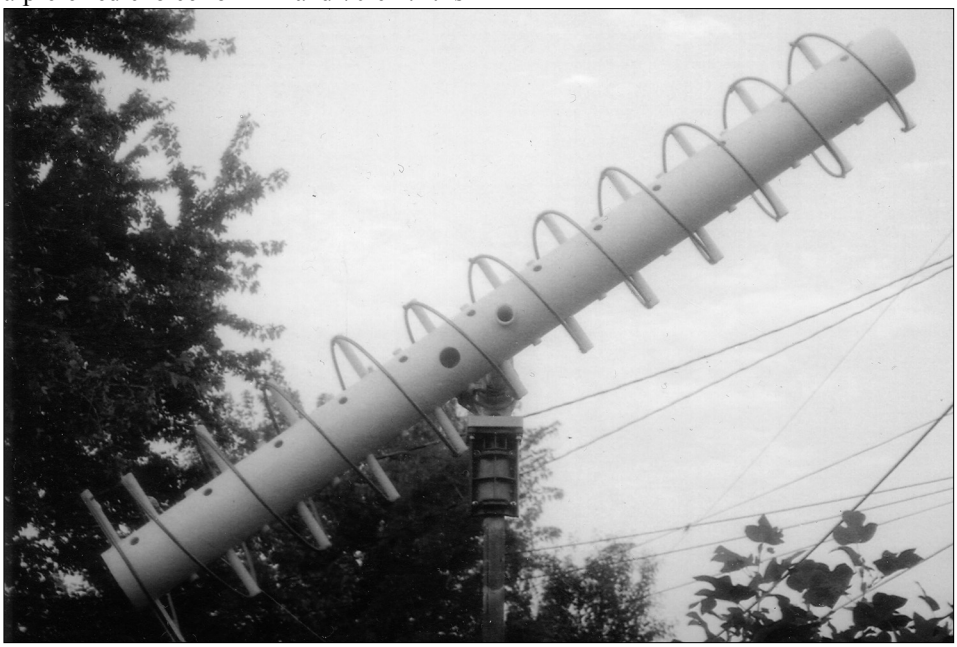

Photo 1: My first helix using AF9Y's [4] design. Built for AO-40, it used all parts from the local hardware store.

When drilling a boom for spreader locations some precision is necessary unless you want your spreaders out of alignment like a porcupine's back. Use one reference point for all measurements such as one end of the boom or a common edge. Do not measure from one spreader location to the next compounding your errors. Recheck your measurements and perform a visual of your work. Both sides of the boom should be marked separately then one side should be drilled then the boom flipped and the other side drilled. Mark, center punch, pilot drill, then complete the spreader's final hole. The drill size should match the spreader diameter. If any spreaders are out of alignment, a spreader hole may be elongated slightly to help bring it into alignment.

If you use a PVC boom, you've added the task of working on a round surface. A straight reference line is needed. Sometimes a repeating character in the printing may be used to create this line. If this is not possible, a square straight piece of stock can be positioned against the PVC on a flat surface to create a line. To determine a line at 180° on the opposite side of the boom, graph paper may be used. Scotch® tape the graph paper's line to the reference line and wrap the paper around the boom. Mark the paper where it intersects with the reference line at 360°. Remove the paper and measure/mark half the distance. Re-tape the graph paper to the reference line and mark the 180° point on the opposite side of the boom.

The Spreaders

The first choice is normally fiberglass followed by wood dowel, then PVC/CPVC. Most helix projects use fiberglass spreaders, which can be secured to the boom with stainless steel set screws and/or glue. Menards and Lowes have an excellent selection in their sign department of ¼ inch and 8-mm diameter fiberglass drive way markers. Bicycle flagsticks may also be used. The drill size should be the same diameter as the spreaders for a snug fit. If you purchase 8 mm rod, you will need an 8 mm drill bit. The 2401 MHz helix doesn't use spreaders as the helix is wound directly on one-inch diameter PVC.

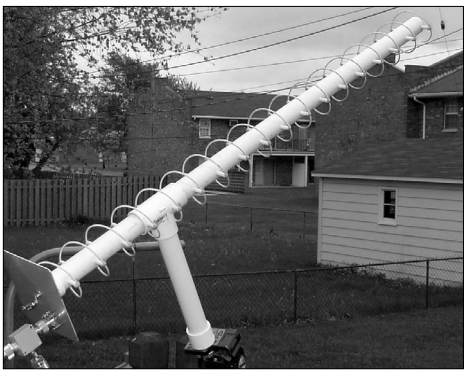

Photo 3: 1269 MHz helix using PVC boom with fiberglass spreaders. The solid reflector is 0.6 wavelength and uses a VE3NPG [8b] matching system.

Photo 2: PVC imagination was used to make a PVC version of G6LVB's quadruple helix [7]. Each antenna was held in place by set screws for removal and tuning. The cut T-section fits to the mast held by two hose clamps.

Aluminum, PVC and fiberglass all have their issues. A build using an aluminum square tube boom will progress quickly due to the type of metal and its flat surfaces. With PVC, the round surface and the task to align and drill the spreader holes properly will slow a build. PVC clogs drill bits and creates dust with sanding so use breathing protection. Fiberglass is very different. It splinters and produces dust when sawing or drilling. Dust from fiberglass becomes airborne and is a definite breathing hazard. **Gloves and breathing protection should absolutely always be used.** From personal experience some splinters always make their way into the fingers. The irritation is not a good feeling and lasts several days. Use caution when building any project with fiberglass.

The Helix

Helical conductor size is debatable and varies widely from builder to builder. *The ARRL Antenna Manual* states: "conductor size should be between 0.006λ and 0.05λ." [6] If this calculation is followed, the minimum diameter would be .485in. or #0000 AWG at 146 MHz, .163in. or (#6 AWG) at 435 MHz. Both the satellite handbook and antenna manual then make exceptions. They state: "smaller diameters have been used at 144 MHz" [6] … and "at 146 MHz the helical element may be wound from 1/4 inch flexible copper tubing" [2] and "at 435 MHz and higher frequencies, #12 wire is acceptable." [2]

Copper, aluminum and coax are the choices. Copper is becoming expensive, but its ease of use makes it a good choice. If you can find it, a 50 foot long coil of ¼ inch refrigerator tubing now costs about $40.00. I used insulated #14 solid copper house wire on 1.2 GHz and 2.4 GHz projects. It was easy to form for the small diameters required at those frequencies. The same practices apply to a helix project as with copper plumbing. Before soldering copper it should be cleaned and polished removing any enamel or oxidation. There is nothing more frustrating then not being able to solder two pieces of copper together, which should be an easy task. When purchasing copper wire, try to maintain its natural form when it is pulled off the spool avoiding bends and kinks. This allows you to use its natural form to easily shape the helix. This same goal applies to ¼ in. copper tubing. The homebrewer should transform this natural coiling into a helix.

Aluminum should be considered because

"Helix Junkie" continues on page 27 ...

PROCEEDINGS OF THE AMSAT-NA

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- Software Technology on ARISSat-1
  by Tony Monteiro, AA2TX
- AMSAT-Fox Preview
  by Tony Monteiro, AA2TX
- AMSAT NextGen CubeSat Proposal – Evolutionary Leveraging of Assets and Opportunities
  by NextGen Satellite Team – Alex Harvilchuck, N3NP
- Ham TV Experiment On-board ISS
  by F Azzarello, IW8QKU, E. D'Andria, I0ELE, T. Giagnacovo, IZ0LTG, and P. Tognolatti I0KPT
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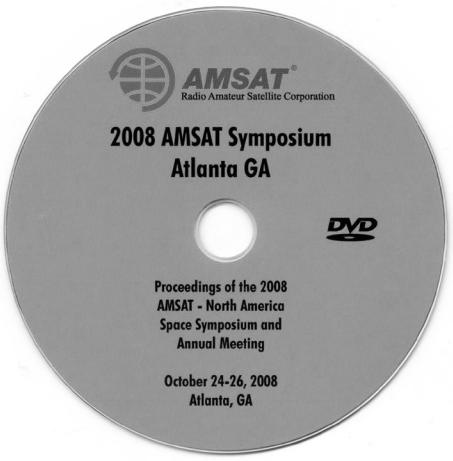

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"Helix Junkie" continued from page 25 ...

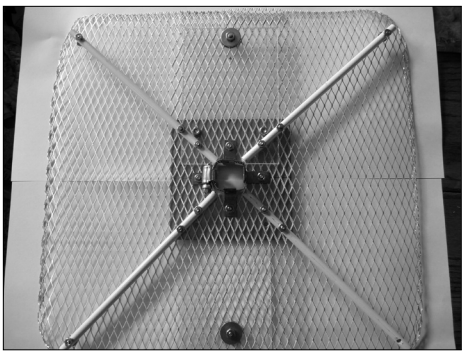


Photo 4: A 0.6 wavelength reflector for 436MHz. The center angle brackets allow the reflector to be moved along a square boom then secured with a hose clamp.

of its low cost and low weight. It is usually found as clothes line wire both bare and insulated. Cost is about $4.00 for a coil of 50 feet. Since aluminum wire is very rigid and seeks to maintain its natural coiled form, use this to your advantage. Aluminum clothesline

Photo 5: A good look at VE3NPC's matching system used with a copper helix.

wire is normally #12 and its coiled form is very close to 436 MHz diameter. It cannot be soldered to the "N" connector and 50-ohm matching choices become limited. VE3NPC neatly addresses both these issues in past issues of *The AMSAT Journal* [8] in which he moves the matching mechanism onto the reflector (Photo 5) and mechanically

Photo 6: It's much easier to homebrew on a flat surface.

connects the aluminum helix to the "N" connector's center pin.

Although I have never used coax, the antenna handbook states it can be used as a helix at 146 MHz "with the inner conductor and the outer braid shorted together [2]." Coax is also used in a 436 MHz helix project in *The ARRL Antenna Handbook*. [6]

The Reflector

The reflector size is normally .6 to 1.1wavelength (λ). This is another subject open for debate, but 0.6λ is a good size to design at 70 cm and 2 m. Since reflector size and wind load become issues at 144 and 436MHz, mesh/screen or a solid reflector with holes is desirable. At 1269 or 2401 MHz, solid reflectors can be made with ease up to 1.1λ. When looking for reflector material anything is possible from a pizza pan to chicken wire, so keep an open mind when cruising hamfests or shopping. For a recent 70 cm project, I found aluminum cooking screen (Photo 4) in the outdoor grill department at large discount store. Less popular is the ring reflector that is 1λ in circumference as shown in Photo 1, which I have used with good success on two 436 MHz antennas.

Part 2 of this article will discuss the remaining topics and helix tales.

References

[1] "BBQ Grill Blues" by VA3BJD, http://www.amsat.org/amsat/archive/amsat-bb/200302/msg00237.html

[2] "*The Satellite Experimenters Handbook*", ARRL, 1983, pages 6-16 to 6-18.

[3] VE3KL's calculator: http://www.rac.ca/tca/2006-01%20Helix%20Design%20Calculator.html

[4] AF9Y: "A New Helix Antenna Design for the Mars Observer Experiment", http://www.af9y.com/helix.htm

[5] DX Engineering Type DXE-SSVC-2P

[6] *The ARRL Antenna Book*, 19th Edition, pages 19-24 and pages 19-28.

[7] G6LVB's project: http://www.g6lvb.com/quadruple_helix.htm

[8] Articles by Clare Fowler, VE3NPC, all in *The AMSAT Journal*:

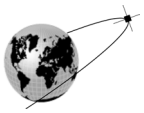
a. "An L-Band Helix Antenna Array" March/April 2004, pages 23-27.

b. "The Development of a Quarter Wave Match for Helix Antennas", November/December 2005, Pages 16-17.

c. "Real World Helix Antenna Comparison Measurements" May/June 2006, Pages 16-20.

d. "Additional Real World Helix Antenna Comparison Measurements" July/August 2007, Pages 5-6.

e. "A 52-Turn Helix for S-Band that Overperforms" September/October 2008, Pages 8-10.



Apogee View - continued from page 21 ...

to download telemetry and data, listen to various greetings of school children on the downlink, enjoy the SSTV images or utilize the transponder, please take a minute to consider the significant contributions of the entire ARISSat-1 team that made this opportunity a reality. AMSAT is dependent upon hard working and dedicated volunteers willing to take an idea and make it a reality. Let's enjoy the fruits of those who labored and give thanks to those that have made it possible.

Report from the 2010 AMSAT Space Symposium

by JoAnne Maenpaa, K9JKM, k9jkm@amsat.org

Welcome to Chicago

AMSAT members met at the 2010 AMSAT Annual General Meeting and Space Symposium held near Chicago, in Elk Grove Village, an adjoining suburb, between October 7 to October 10, 2010. The sessions featured:

- Board of Directors Meeting
- Space Symposium with Technical Presentations
- Live Demonstrations
- AMSAT Annual Group Meeting
- Tour of the Fermi National Accelerator Laboratory

AMSAT President Barry Baines, WD4ASW, noted our remarkable achievements in his welcome message. We have made significant steps in the policy direction which began in 2009 to get AMSAT back into space. One of the most popular Amateur Radio in space projects ever, SuitSat II was re-developed into ARISSat-1 in response to changes in the schedule and storage aboard the International Space Station. Two ARISSat satellites have been built, tested and delivered to NASA. This included a primary flight model and an operational backup satellite. The primary flight satellite will be released into orbit from the ISS in early 2011 due to the efforts of AMSAT's high achieving team of satellite developers and builders.

Educational Outreach Key to AMSAT Growth & Already Producing Results

In his opening remarks Barry also noted the strengthened ties between AMSAT and the educational community with the extension of the mentorship program involving AMSAT, the IBM Watson Research Center and SUNY-Binghamton on the NextGen CubeSat development program.

The Board of Directors voted to approve the Memorandum of Understanding between AMSAT and the University of Florida, Gainesville to embark upon an educational outreach program. Discussion with University of Florida's Dr. Norman Fitz-Coy, who leads a graduate CubeSat development program, has revealed several opportunities for AMSAT members to mentor the students on electronics and system engineering issues including on-orbit satellite management learned from operating AMSAT's fleet of spacecraft. AMSAT will also offer assistance with ground station development and operation.

The AMSAT Board of Directors also voted to continue with the educational outreach project between AMSAT, Binghamton University - SUNY and IBM's Heritage Corridor Center for Advanced Studies. The NextGen Satellite Program is lead by Alex Harvilchuck, N3NP. During the first year of this cooperative effort the NextGen student team characterized supercapacitor performance in vacuum and developed an engineering model of deployable solar cells on a 3U CubeSat.

AMSAT Vice-President of Engineering Tony Monteiro, AA2TX, discussed plans for development of AMSAT's Project Fox CubeSat and this project's significant impact on the educational community. One goal for project Fox is to establish development of "standardized" CubeSat components including reliable software-defined transponders, telemetry downlink and spacecraft power management. A stable, well-documented, standardized "CubeSat bus" can be made available to university CubeSat development teams, freeing them to concentrate on the science of their research programs. This will have the net effect of having an amateur transponder flying in many CubeSats in the future. The NextGen partnership with AMSAT-SUNY-IBM will perform the system engineering leveraging on AMSAT's pioneering Project Fox CubeSat.

AMSAT's educational outreach program provides several advantages to ensure the continued growth of Amateur Radio in space by training the next generation of space engineers:

- AMSAT establishes a presence at major universities with state-of-the-art facilities and satellite development teams.
- Potential for student projects focused on AMSAT needs.
- Broadening of AMSAT's presence in the wider university community.
- Increased potential for involvement with research/development grant-funded opportunities for AMSAT and AMSAT members.
- Establishing a program that offers significant traction for further education outreach.

The election of AMSAT's Senior Officers was one of the first orders of business to be settled once the AMSAT Board of Directors meeting opened on October 7. See Table 1 for the election results.

Table 1: 2010-2011 AMSAT Senior Officers

President	Barry Baines, WD4ASW
Vice-President Operations	Drew Glasbrenner, KO4MA
Vice-President User Services	Gould Smith, WA4SXM
Vice-President Engineering	Tony Monteiro, AA2TX
Secretary	Alan Biddle, WA4SCA
Treasurer	Keith Baker, KB1SF/VA3KSF
Manager	Martha Saragovitz
Executive Vice-President Vice-President Human Spaceflight Vice-President Marketing	These positions are not filled at this time

ARISSat-1 Was Operating at the Symposium

All of the technical details of ARISSat-1 will be presented in several articles in this and upcoming issues of *The AMSAT Journal*. You can get a preview of ARISSat-1 and meet some of the team responsible for the success of AMSAT's next satellite in the photos. [Ed. - Due to space considerations most of the photos associated with this article will be published next month. Apologies for the delay, but I'm out of space.]

Attendees at the Symposium enjoyed an excellent series of speakers, demonstrations, and slide presentations. The 2010 Symposium Proceedings are available from the AMSAT Store. Table 2 provides a list of the papers presented.

AMSAT Awards

AMSAT is grateful for the dedicated support of our volunteers. Here is the list we thank and congratulate for your efforts on behalf of Amateur Radio in space:

Tony Monteiro, AA2TX, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT leading the ARISSat-1 satellite software development, writing the SDX software, and software testing.

Dave Jordan, AA4KN, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your service to AMSAT in contributing in many ways to the construction of ARISSat-1 and preparing the audio greetings and spoken telemetry audio.

Carl Zelich, AA4MI, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your service to AMSAT by your volunteer work at the ARISSat-1 lab.

Hank Sill, AC4ZI, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in helping to get the ARISSat-1 satellite ready to fly.

John Spasojevich, AG9D, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT Symposium. Your attention to the many details and arrangements helped ensure the success of the Chicago, Illinois AMSAT Symposium.

Olon Henderson, AJ4HP, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your service to AMSAT by your volunteer work at the ARISSat-1 lab.

Claire Fredlund is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in producing the Safety Data Package for ARISSat-1.

John Charais is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in getting the ARISSat-1 satellite power system ready to fly.

Mark Steiner, K3MS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in contributing to the ARISSat-1 satellite program.

Chuck Pinkham, K3PER, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT User Services. With gratitude for your continued service to AMSAT at Dayton and being an integral part of the Dayton team.

Jim Diggs, K4AHO, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your service to AMSAT in contributing to the ARISSat-1 satellite program.

George Presley, K4RSV, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your service to AMSAT in providing invaluable test engineering hardware, facilities, mentoring, and testing of the ARISSat-1 satellite.

Clint Bradford, K6LCS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in promoting AMSAT at hamfests, clubs and gatherings.

Steve Coy, K8UD, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT by representing AMSAT at numerous hamfests and at the Dayton Hamvention.

John Papay, K8YSE, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding

Table 2: 2010 Symposium Technical Presentations and Papers	
AO-51 Battery Capacity & Spin Trends	Mark Hammond, N8MH and Colin Hurst, VK5HI
Characteristics GEO-Eagle Data Multicast	Paul Wiedemeier, KE5LKY
Amateur Radio on the ISS - Operations Update	Keith Pugh, W5IU
Successful Hamfest Satellite Demonstrations	Keith Pugh, W5IU
AMSAT-FOX Preview	Tony Monteiro, AA2TX
University of Louisiana Satellite Program	Nick Pugh, K5QXJ
ElmerSat - A Modest Proposal	Tom Clark, K3IO
Psat and APRS Space Network	Bob Bruninga, WB4APR
NextGen Satellite (AMSAT, IBM, SUNY-Binghamton)	Alex Harvilchuck, N3NP
ARISSat-1 Overview	Gould Smith, WA4SXM
ARISSat-1 Software Radio Technology	Tony Monteiro, AA2TX
BPSK-1000 format for ARISSat-1	Phil Karn, KA9Q
ARISSatTLM - Software Demodulator & Telemetry	Douglas Quagliana, KA2UPW
Calculating Available Power (ARISSat & Fox)	Robert Davis, KF4KSS
ARISSat-1 Power System	Tony Monteiro, AA2TX
Assembling ARISSat-1	Gould Smith WA4SXM
ARISSat-1 Vibration Testing	Robert Davis KF4KSS
AMSAT and ITAR: Lessons Learned	Barry Baines WD4ASW
Codec2 Alpha V0.1 under the LGPL license	Bruce Perens K6BP
Computerized, Low Cost, Satellite Tracking System	Mike Stipick KC4RI
Flex Radio V/U Module - 2m/70cm Transverter	Bob McGwier N4HY
100 Watt VHF/UHF Amplifier Design & Construction	Stephen Turner K3HPA
ARISS = Education	Rosalie White, K1STO
Education Paradigm Shift for AMSAT to Support Subsidized Launch Opportunities	Mark Spencer, WA8SME
HamTV Experiment on-board ISS	F. Azzarello, IW8QKU
A lightweight 20 foot stressed dish for 1296 MHz EME	Marc Franco, N2UO
Getting the AMSAT Word Out	JoAnne Maenpaa, K9JKM
How to Work the FM Ham Satellites With Your Handheld Radio	Clint Bradford, K6LCS

contributions to AMSAT Operations. With gratitude for your initiative and support in protecting our satellite frequencies from QRM, educating errant users, and encouraging activity.

JoAnne Maenpaa, K9JKM, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to a wide range of AMSAT Activities. Your involvement with a myriad of AMSAT activities is mind boggling. As an ANS Editor, you help produce a weekly news bulletin that is well recognized as a source of timely, informative source on AMSAT and amateur satellite-related news items. You have assisted the editor of the AMSAT JOURNAL in the handling of articles and working with authors on their submissions. As a member of this year's Symposium Committee, you have handled the paper submission process and counseled the Committee on how the AMSAT Symposium traditionally handles things. Your willingness to 'get involved' and make a difference is deeply appreciated.

Jim Johns, KA0IQT, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in providing software for the ARISSat-1 satellite.

Douglas Quagliana, KA2UPW, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in developing the Windows version of the BPSK-1000 ground station software the ARISSat-1 satellite.

Phil Karn, KA9Q, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in developing the new BPSK-1000 protocol for the ARISSat-1 satellite.

Carol Jackson, KB3LKI, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in contributing to the ARISSat-1 satellite.

Dean Holste, KC9EOQ, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the 2010 AMSAT Symposium. Your work with the 2010 AMSAT Symposium Committee registration and as the conference site treasurer helped ensure the success of the Chicago, Illinois AMSAT Symposium.

Dick Jansson, KD1K, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in providing thermal models for the ARISSat-1 satellite.

Doug Papay, KD8CAO, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your support of the AO-51 Operations Group.

Bob Davis, KF4KSS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT Engineering Team. With gratitude for your continued service to AMSAT in designing the ARISSat-1 structure and leading the vibration testing.

Eric Christensen, KF4OTN, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT User Services. With gratitude for your continued service to AMSAT in managing the responses to questions that come into the AMSAT Web site.

Joe Armbruster, KJ4JIO, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT Engineering Team. With gratitude for your contributions to AMSAT by delivering many services needed to build and test the ARISSat-1 satellite.

Bruce Paige, KK5DO, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT User Services. With gratitude for your dedicated service to AMSAT in producing the outstanding AMSAT Awards, working on the AMSAT online store, and operating the AMSAT Net.

Joe Fitzgerald, KM1P, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in providing a solar panel simulator and your work to improve AO40Rcv software used in the development and testing of ARISSat-1.

Drew Glasbrenner, KO4MA, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT at Dayton, representing the organization at numerous hamfests throughout the year, serving as an AO-51 command station, and participating in the Engineering Task Force.

Lee McLamb, KU4OS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your dedicated service to AMSAT in producing the weekly AMSAT NEWS Service.

Chuck Green, N0ADI, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT Engineering. With gratitude for your service to AMSAT in testing, building, and getting the ARISSat-1 satellite ready to fly.

Garry Tuttle, N2EOX, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your service to AMSAT by your volunteer work at the ARISSat-1 lab.

Gilbert Mackall, N3RZN, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in developing the Mac version of the BPSK-1000 ground station software the ARISSat-1 satellite.

Kenneth Ransom, N5VHO, is presented the 2010 AMSAT Achievement Award in recognition of your ongoing leadership over the years in working with ARISS to coordinate with and train the astronauts at NASA Johnson Space Center, and for tracking all factors that determine when ARISS educational events can take place. Kenneth continues to be the person who works between the Astronaut Office, the NASA ISS Program Office, and the ARISS Team. He coordinates with the very busy astronauts who may not see the need for ARISS or spending time studying for an Amateur Radio license... until Kenneth convinces them. But even more importantly, he keeps his fingers on all of the factors that must align in order to schedule the ARISS QSOs day in and day out.

Mark Severance, N5XWF, is presented the 2010 AMSAT Achievement Award in recognition of your

outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in contributing to the ARISSat-1 satellite program.

Bill Ress, N6GHZ, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT and its Engineering Task Force. For the past two years, you have served AMSAT in a variety of ways. As a member of the Board of Directors, you pushed AMSAT to establish realistic and achievable goals for maintaining Amateur Radio in space. As chairman of the Engineering Task Force, you led a concerted effort to develop a space strategy that was embraced by the AMSAT Board of Directors and resulted in the decision to proceed with Project Fox. As a member of the Radioskaf-V/ARISSat-1 team, you built critical RF hardware. Your dedication to meeting standards of excellence and desire to see AMSAT succeed has made a significant difference to AMSAT.

Steve Bible, N7HPR, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in the development of the ARISSat-1 satellite command receiver and decoder boards.

Ed Clayo, N8BBQ, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your support of the AO-51 Operations Group.

Mark Hammond, N8MH, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your dedicated service as a command station of AO-16 and AO-51.

Greg Braun, N9CHA, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the 2010 AMSAT Symposium. Your attention to the many details and arrangements helped ensure the success of the Chicago, Illinois AMSAT Symposium.

Stephen Belter, N9IP, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions enhancing AMSAT's visibility, status, and interactions with the wider amateur community. Over the course of the past year, you have ensured that coverage of key AMSAT presentations at the Dayton Hamvention and AMSAT Symposium have been made available to the wider amateur community through professional recordings. You also undertook the very delicate task of developing an Acceptable Use Policy for the AMSAT Bulletin Boards. This required a measured balance to ensure the continued open flow of ideas which are the tradition of AMSAT, with the need to ensure an acceptable level of decorum and respect. The result has been a greater emphasis on our traditional interests without compromising our customs.

Joe Julicher, N9WXU, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT in getting the ARISSat-1 satellite ready to fly.

Jerry Zdenek, N9YTK, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in developing major hardware and software components for the ARISSat-1 satellite.

Dee Interdonato, NB2F, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your dedicated service to AMSAT in producing the weekly AMSAT NEWS Service and additional duties for the Field Operations Team.

Bill Muhr, NF9D, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the 2010 AMSAT Symposium. Your attention to the many details and arrangements helped ensure the success of the Chicago, Illinois AMSAT Symposium.

Bill Reed, NX5R, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in providing software for the ARISSat-1 satellite.

Ib Christoffersen, OZ1MY, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your support of the AO-51 Operations Group.

OZ7SAT, AMSAT-OZ, is presented the 2010 AMSAT Achievement Award in recognition of their outstanding contributions to AMSAT Operations. With gratitude for your telemetry collection and support of the AO-51 and IO-26 command teams.

Sergey Samburov, RV3DR, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT ARISSat Team. With gratitude for your contributions to the ARISSat-1/RadioSkaf V satellite program.

Valery Pikkiev, RW3WW, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT ARISSat Team. With gratitude for your contributions to the ARISSat-1/RadioSkaf V satellite program.

Sergey Borodin, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your contributions to the ARISSat-/RadioSkaf V satellite program.

Tim Moffat, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in getting the ARISSat-1 satellite ready to fly.

Colin Hurst, VK5HI, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your service to AMSAT for telemetry analysis and support of the AO-51 Command Team and Operations. Your detailed analysis has made possible a deeper understanding of the AO-51 spacecraft functions and significantly improved our ability to optimize usage and extend its operating life.

Mike Welch, W1MNW, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your service to AMSAT by your volunteer work at the ARISSat-1 lab.

Rick Hambly, W2GPS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in keeping the AMSAT Web site operational and providing invaluable support.

Lou McFadin, W5DID, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in getting the ARISSat-1 satellite ready to fly, and your work with the Engineering Task Force. Your time and efforts have made it possible, yet again!

Keith Pugh, W5IU, is presented the 2010 AMSAT Achievement Award in recognition of your ongoing leadership, volunteering for six-month stints as ARISS school scheduler and coordinator, working for many years as an ARISS Mentor of schools, and for being "the Spirit of ARISS." Keith is a volunteer who seldom says no. When you ask him to do a task, you know it will be done, and done correctly. If you ask him to take a leadership role, he will step up to the plate with the reply of "I will do the best I can," and he does. He is the role model for "the Spirit of ARISS." He has many important duties within ARISS, and in addition, regularly sponsors demos of ARISS and AMSAT satellites at Dayton and a number of yearly events.

Larry Brown, W7LB, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in building the development and flight cables for the ARISSat-1 satellite.

James French, W8ISS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in producing the AMSAT Satellite Report.

Kermit Carlson, W9XA, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT 2010 Symposium. Thank you for leading the effort to make the 2010 AMSAT Symposium at Chicago a success. Your willingness to take on the planning and implementation of the Symposium is gratefully appreciated. Your management skills in handling the myriad of details as well as creating the A/V environment for the presentations has resulted in a well-executed Symposium. Thank you for making our Symposium in Chicago a very successful and enjoyable one!

Stan Wood, WA4NFY, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your continued service to AMSAT in contributing to ARISSat-1 testing and making the satellite ready to fly.

Alan Biddle, WA4SCA, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions as AMSAT Corporate Secretary. Over the course of the past year, you have handled a number of "special projects" as well as fulfilled your responsibilities as Corporate Secretary. Along with releasing the minutes of the 2009 BOD meeting in record time, you agreed to handle several critical 'one time' projects as well. This included serving as Moderator of the AMSAT Forum at the 2010 Dayton Hamvention, handling the process of collecting and preparing the paperwork necessary for our recognition of AMSAT volunteers, participating in the Bulletin Board AUP committee, and serving as secretary/'scribe' at the ARISSat-1 Design Review that took place in Orlando in February 2010. In each case, you handled your tasks in a timely, thoughtful and detailed manner which substantially enhanced the quality of work done in these areas. Thank you for your willingness to handle these requests in an effective and timely manner.

Ed Long, WA4SWJ, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your dedicated service to AMSAT in producing the outstanding *AMSAT Journal*.

Gould Smith, WA4SXM, is presented the 2010 AMSAT Achievement Award in recognition of the critical role you fulfilled in the successful completion of ARISSat-1; management of AMSAT's presence at Dayton Hamvention; and maintaining timely information on the AMSAT Web site. The completion of Radioskaf-V/ARISSat-1 wouldn't have happened without your direct involvement. You have spent more than two years providing leadership as project manager and successfully establishing a team that worked together to re-engineer the satellite from a 'SuitSat' to a space frame. You ensured that team members were aware of deadlines and the ramifications of missing those deadlines. You spent hours not only handling project management functions, but testing systems, conducting vibration and thermal/vac tests in Orlando, and providing documentation for the Payload Safety Review. You represented AMSAT at the Payload Safety Review in Johnson Space Center, Houston. Your ability to work with people and to handle the myriad of technical details resulted in completion of a satellite that has significant educational and strategic importance to AMSAT and is of significant interest to NASA and RSC-Energia. While embroiled in the development of ARISSat-1, you fulfilled your responsibilities as VP-User Services, managing AMSAT's presence at Dayton, working with your team to ensure that *The AMSAT Journal* and ANS maintained their quality of product, and providing guidance to the Symposium Committee in preparation to this year's Symposium. You updated the publications that you've written in the past and had the new versions available at Dayton as well as worked to maintain timely information on the AMSAT website. Every week, AMSAT has benefited from your dedication and hard work.

Ray Hoad, WA5QGD, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in updating the weekly Keplerian elements on the AMSAT Web site.

Kevin Schuchmann, WA6FWF, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your dedicated service as a command station of AO-51.

John Kingelhoeffer, WB4LNM, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Engineering. With gratitude for your service to AMSAT in designing the command receiver for the ARISSat-1 satellite.

Mike Young, WB8CXO, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in producing, testing and supporting the popular LVB Tracker boxes.

Barry Baines, WD4ASW, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT ARISSat Team. With gratitude for your service to AMSAT in contributing to the ARISSat-1 satellite program.

Patrick Stoddard, WD9EWK/VA7EWK, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your work as an ambassador of amateur satellites, and as a role model and pathfinder for portable operators everywhere.

Bob Schwerdlin, WG9L, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to MSAT Engineering. With gratitude for your service to AMSAT in providing mechanical drawings needed to develop the ARISSat-1 satellite.

The AMSAT Board of Directors and AMSAT Manager, L-R: Tom Clark, K3IO; AMSAT Manager Martha Saragowitz; Drew Glasbrenner, KO4MA; Lou McFadin, W5DID; Tony Monteiro, AA2TX; Barry Baines, WD4ASW; Gould Smith, WA4SXM, not pictured Alan Biddle, WA4SCA.

Steve Kenwolf, WH6BSZ, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT User Services. With gratitude for your continued service to AMSAT in producing great designs.

Carmine Fiorello, WK6C, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to the AMSAT ARISSat Team. With gratitude for your continued service to AMSAT by providing solar panel simulator hardware used in the development and testing of ARISSat-1.

Allan Saul, ZS1LS, is presented the 2010 AMSAT Achievement Award in recognition of your outstanding contributions to AMSAT Operations. With gratitude for your support of the AO-51 Operations Group.

Prize Donors

AMSAT appreciates the support shown by these companies and individuals with their donations of prizes for the 2010 AMSAT Space Symposium.

- ICOM – Grand Prize IC-7000 Transceiver
- American Radio Relay League
- Flex Radio
- AES - Amateur Electronic Supply
- Ham Radio Outlet
- Yaesu
- Kenwood
- CQ Amateur Radio
- Cable Experts
- Radio Dan
- QSL-Man
- West Mountain Radio
- Telepost Inc.
- Martha Saragovitz
- Barry Baines – FT-847 Transceiver

Vote of Thanks for the Symposium Volunteers

AMSAT acknowledges and thanks the dedicated efforts of the Symposium Committee who helped organize this year's show:

Kermit Carlson, W9XA – Chairman
Bill Muhr, NF9D
Dean Holste, KC9EOQ
John Spasojevich, AG9D
Greg Braun, N9CHA
JoAnne Maenpaa, K9JKM

Thanks are also in order to Ron Steinberg, K9IKZ, who runs RentCom where we were able to rent the professional grade audio/visual systems at a substantial discount. Ron says it's his way to give back to ham radio.

Art Feller, W4ART, provided the photography. Additional photos of the Symposium can be viewed on-line at Art's Gallery, see: http://www.afeller.us/Studio_dArt/Personal_Galleries/Pages/AMSAT_2010.html

2010 Symposium Chairman Kermit Carlson, W9XA (left) and AMSAT-NA President Barry Baines, WD4ASW (right).

(Left) ARISSat-1 Project Manager Gould Smith, WA4SXM, was congratulated by (right) AMSAT President Barry Baines, WD4ASW, for completion of two satellites – the primary flight unit and an operational backup unit. These satellites have been shipped to Russia for final integration and testing prior to being loaded on a Progress cargo flight to the International Space Station in January, 2011. [Ed. - ARISSat-1 is in orbit now!]

Reach for the stars.

N3UC, formerly N4USI, control operator of AO-27, says, "AO-27 may be getting old and failing at times, after 15 years circling the earth. But, my IC-910H that I use to control AO-27, using data transmissions, has never failed me".

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AO-27, SO-50, AO-51, and VO-52.

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